Analysis of Lung Cancer Mortality in Females and Leukemia Mortality in Males and Females for the Towns of Barnstable, Bourne, Falmouth, Mashpee, and Sandwich, 1969-1985.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY.....i

INTRODUCTION

I. Purpose.....1
II. Background.....1
A. The Upper Cape.....1
B. History of the Problem.....2
III. Existing Environmental Data.....4
A. General Upper Cape Environment.....4
B. Water Data.....5
1. Metcalf and Eddy Report.....6
2. Weston Report.....7
3. U.S. Geological Survey Studies.....8
4. U.S. Air Force Sampling.....10
5. E.C. Jordan Monitoring.....10
6. Barnstable Co. Health and Environmental Dept. Studies.....11
7. Other Potential Groundwater Sources.....13
C. Air Data.....13
1. Power Plants.....14
2. Propellant Bag Burning Sites.....15
3. Fire Training Sites.....16
4. Fuel Dump Sites.....17
D. Other Environmental Data.....17
IV. Scope of the Project.....18
V. Objectives of the Study.....19
A. Recalculation of Standardized Mortality Ratios (SMRs).....19
B. Environmental Analyses.....20

METHODS

I. Study Design.....22
II. Population.....23
III. Sampling Frame.....23
A. Cases.....23
B. Controls.....24
IV. Determination of Eligibility.....25
A. SMR Calculation.....25
B. Environmental Analyses.....25
1. Establishment of a Time Window of Relevant Exposure.....25
2. Definition of an Eligible Residence.....29
3. Minimum Residence Requirements.....30
4. Exclusion of Residential History Accrued Prior to 1940.....31
5. Examples of the Application of Various Exclusion Rules.....31
6. Summary.....33
V. Data Collection.....35
A. Overview.....35
B. Residential Histories - Town Directories.....37
C. Residential Histories - Telephone Interviews.....38
1. Identification and Location of Informants.....38
2. Blinding.....41
3. Interview Administration.....43

TABLE OF CONTENTS (CONT.)

VI. Measurement of Exposure..45
A. Mapping..46
B. Distance of Residence from Suspected Sources of Environmental Contamination - Lung Cancer...................47
C. Distance Variables - Leukemia..48
1. Distance from the MMR..48
2. Distance of Residence from the Mashpee Landfill...........................49
3. Distance of Residence from PAVE PAWS......................................50
D. Duration of Residence..51
E. Distance-Duration Exposure Score...51
VII. Control Variables..53
VIII. Data Analysis...54
A. Standardized Mortality Ratios..54
B. Environmental Analyses...56

RESULTS

I. Study Population...60
A. Response Rate..60
1. Lung Cancer..60
2. Leukemia...62
B. Time Between First Year of Residence and Death.............................63
C. Eligibility..66
D. Age..68
E. Smoking Status...70
F. Occupation at Time of Death..71
G. Causes of Death for Controls...72
II. Analytic Results..74
A. Standardized Mortality Ratios..74
B. Environmental Analyses...75
1. General Mapping Results..75
2. Distance to Suspected Air Pollution Sites - Lung Cancer...................77
a. Canal Electric Plant...77
b. Propellant Bag Burning Areas...78
c. Fire Training Areas..83
3. Distance to Suspected Groundwater Contamination Sites - Leukemia...........85
a. Massachusetts Military Reservation...85
b. Mashpee Landfill...86
4. Other "Distance" Analyses - Leukemia.......................................87
a. Canal Electric Plant...87
b. PAVE PAWS Site...88
c. Groundwater Plume Areas..88
5. Duration of Residence - Lung Cancer..89
6. Duration of Residence - Leukemia...91
7. Exposure Score - Lung Cancer...92
8. Exposure Score - Leukemia..96

TABLE OF CONTENTS (CONT.)

DISCUSSION

I. Standardized Mortality Ratios....................................98
II. Environmental Analyses...100
  A. Interpretation of Findings - General Considerations.........100
    1. Plausibility of the Hypothesized Associations............101
    2. Appropriateness of Exposure Assessment...................105
    3. Temporal Relationship....................................107
  B. Mapped Residences...108
  C. Distance to Suspected Sources of Envir. Contamination.......110
  D. Case-Control Analyses.......................................111
    1. Interpretation - General Considerations..................111
    2. Distance to Suspected Environmental Sites................118
    3. Duration of Residence....................................119
    4. Exposure Score...120
III. Summary...122
  A. SMR Analyses..122
  B. Environmental Analyses......................................122

CONCLUSIONS/RECOMMENDATIONS..127

BIBLIOGRAPHY

FIGURES

TABLES

APPENDICES

TABLE OF CONTENTS (CONT.)

LIST OF FIGURES

Figure 1: Map of the Upper Cape

Figure 2: Map Illustrating the Upper Cape Environmental Sites Listed on Table 6

Figure 3: Map Illustrating the Direction of Groundwater Flow in the Vicinity of the Massachusetts Military Reservation

Figure 4: Map Illustrating the Location of the Mashpee Landfill

Figure 5: Map Illustrating the Azimuth of Radar Coverage of the PAVE PAWS Facility

Figure 6: Map Illustrating the Three Geographic Groupings of Environmental Sites used in the Exposure Score Analyses

Figure 7: Map Illustrating the Location of Known Groundwater Plumes Potentially Affecting Private Wells on the Upper Cape

Figure 8a: Map Illustrating Approximate 1970 Population Density for Barnstable

Figure 8b: Map Illustrating Approximate 1970 Population Density for Bourne and Sandwich.

Figure 8c: Map Illustrating Approximate 1970 Population Density for Falmouth and Mashpee.

TABLE OF CONTENTS (CONT.)

List of Tables

Table 1: Percent Population Increase Between 1970 and 1980 for the Five Upper Cape Towns.

Table 2: Observed and Expected Numbers of Leukemia and Lung Cancer Deaths, 1969-1983, for the Residents of Bourne.

Table 3: Observed and Expected Numbers of Leukemia and Lung Cancer Deaths, 1969-1983, for the Residents of Falmouth.

Table 4: Observed and Expected Numbers of Leukemia and Lung Cancer Deaths, 1969-1983, for the Residents of Mashpee.

Table 5: Observed and Expected Numbers of Leukemia and Lung Cancer Deaths, 1969-1983, for the Residents of Sandwich.

Table 6: Selected Major Sites of Potential Water and Air Contamination on the Upper Cape by Date of Occurrence or Operation, Location of the Site, Nature of the Known or Potential Contamination, and Potential Pathway(s) of Exposure for Residents.

Table 7: Distribution of Lung Cancer Cases and Controls According to Response Category.

Table 8: Distribution of Leukemia Cases and Controls According to Response Category.

Table 9: Distribution of Cases and Controls for Whom Residential Histories were Obtained through Interview According to the Number of Years Between First Year of Residence on Upper Cape Cod and Death.

Table 10: Distribution of Cases and Controls for Whom Residential Histories were Obtained According to the Number of Years Between First Year of Residence on Upper Cape Cod and Death.

Table 11: Number of Subjects with Complete Residential History Used in Various Case-Control Analyses Relating Death from Lung Cancer to Residence on Upper Cape Cod--by Residence Requirement (Number of Years Since First Year of Residence on Upper Cape Cod): Decade of Death = 1969-1978.

Table 12: Number of Subjects with Complete Residential History Used in Various Case-Control Analyses Relating Death from Lung Cancer to Residence on Upper Cape Cod--by Residence Requirement (Number of Years Since First Year of Residence on Upper Cape Cod): Decade of Death = 1979-1985.

TABLE OF CONTENTS (CONT.)

Table 13: Number of Subjects with Complete Residential History Used in Various Case-Control Analyses Relating Death from Leukemia to Residence on Upper Cape Cod--by Residence Requirement (Number of Years Since First Year of Residence on Upper Cape Cod): Decade of Death = 1969-1978.

Table 14: Number of Subjects with Complete Residential History Used in Various Case-Control Analyses Relating Death from Leukemia to Residence on Upper Cape Cod--by Residence Requirement (Number of Years Since First Year of Residence on Upper Cape Cod): Decade of Death = 1979-1985.

Table 15: Age Distributions of Cases and Controls Used in the Analysis of the Relationship Between Exposure to the Upper Cape Cod Environment and Risk of Death from Lung Cancer--Data Obtained from Death Certificates for Subjects with Complete Residential Histories who Met the "10+ Years" Residence Requirement.

Table 16: Age Distributions of Cases and Controls Used in the Analysis of the Relationship Between Exposure to the Upper Cape Cod Environment and Risk of Death from Lung Cancer--Data Obtained from Death Certificates for Subjects with Complete Residential Histories who Met the "20+ Years" Residence Requirement.

Table 17: Age and Sex Distributions of Cases and Controls Used in the Analysis of the Relationship Between Exposure to the Upper Cape Cod Environment and Risk of Death from Leukemia--Data Obtained from Death Certificates for Subjects with Complete Residential Histories who Met the "5+ Years" Residence Requirement.

Table 18: Age and Sex Distributions of Cases and Controls Used in the Analysis of the Relationship Between Exposure to the Upper Cape Cod Environment and Risk of Death from Leukemia--Data Obtained from Death Certificates for Subjects with Complete Residential Histories who Met the "10+ Years" Residence Requirement.

Table 19: Distribution of Cases and Controls with Complete Residential Histories According to Smoking Status (Ever Smoked).

Table 20: Mean Packyears for Ever Smokers--Data Obtained by Informant Interview.

Table 21: Distribution of Lung Cancer Cases and Controls According to Occupation at Time of Death--Data Obtained from Death Certificates for Those Subjects with Complete Residential Histories.

Table 22: Distribution of Leukemia Cases and Controls According to Occupation at Time of Death--Data Obtained from Death Certificates for Those Subjects with Complete Residential Histories.

TABLE OF CONTENTS (CONT.)

Table 23: Distribution of Controls According to Cause of Death--Data Obtained from Death Certificates of Subjects for Whom Residential Histories Were Obtained.

Table 24: Distribution According to Cancer Type of Controls Who Died of Cancer--Data Obtained from Death Certificates of Subjects for Whom Residential Histories Were Obtained.

Table 25: Standardized Mortality Ratios Comparing Observed and Expected Numbers of Lung Cancer Deaths for Short- and Long-Term Upper Cape Cod Residents.

Table 26: Standardized Mortality Ratios Comparing Observed and Expected Numbers of Leukemia Deaths for Short- and Long-Term Upper Cape Cod Residents--by Decade of Death.

Table 27: Distribution of Lung Cases and Controls With Complete Residential Histories According to Distance from Closest Residence to the Canal Electric Plant.

Table 28: Results of Contingency Table Analyses Relating Distance from Closest Residence to the Canal Electric Plant to Risk of Death from Lung Cancer--Data Obtained by Informant Interview.

Table 29: Distribution of Lung Cases and Controls With Complete Residential Histories According to Distance from Closest Residence to the Northeast Propellant Bag Burning Area.

Table 30: Results of Contingency Table Analyses Relating Distance from Closest Residence to the Northeast Propellant Bag Burning Area to Risk of Death from Lung Cancer for Interviewed Subjects--Data Obtained by Informant Interview.

Table 31: Distribution of Lung Cancer Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to the Northwest Propellant Bag Burning Area.

Table 32: Results of Contingency Table Analyses Relating Distance from Closest Residence to the Northwest Propellant Bag Burning Area to Risk of Death from Lung Cancer--Data Obtained by Informant Interview.

Table 33: Distribution of Lung Cancer Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to the West Propellant Bag Burning Area.

Table 34: Results of Contingency Table Analyses Relating Distance from Closest Residence to the West Propellant Bag Burning Area to Risk of Death from Lung Cancer--Data Obtained by Informant Interview.

TABLE OF CONTENTS (CONT.)

Table 35: Distribution of Lung Cancer Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to the South Propellant Bag Burning Area.

Table 36: Results of Contingency Table Analyses Relating Distance from Closest Residence to the South Propellant Bag Burning Area to Risk of Death from Lung Cancer--Data Obtained by Informant Interview.

Table 37: Distribution of Lung Cancer Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to a Propellant Bag Burning Area.

Table 38: Results of Contingency Table Analyses Relating Distance from Closest Residence to a Bag Burning Area to Risk of Death from Lung Cancer for Subjects with Complete Residential Histories.

Table 39: Distribution of Lung Cancer Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to the Fuel Test Valve Dump.

Table 40: Results of Contingency Table Analyses Relating Distance from Closest Residence to the Fuel Test Valve Dump Area to Risk of Death from Lung Cancer--Data Obtained by Informant Interview.

Table 41: Distribution of Lung Cancer Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to Fire Training Areas.

Table 42: Results of Contingency Table Analyses Relating Distance from Closest Residence to the Fire Training Areas to Risk of Death from Lung Cancer--Data Obtained by Informant Interview.

Table 43: Distribution of Leukemia Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to the MMR.

Table 44: Results of Contingency Table Analyses Relating Distance from Closest Residence to the MMR to Risk of Death from Lung Cancer--Data Obtained by Informant Interview.

Table 45: Descriptive Statistics for Duration (in Excess of the Residence Requirement) of Residence on the Upper Cape for Lung Cancer Subjects--Data Obtained by Informant Interview.

Table 46: Descriptive Statistics for Duration (in Excess of the Residence Requirement) of Residence on the Upper Cape for Leukemia Subjects--Data Obtained by Informant Interview.

TABLE OF CONTENTS (CONT.)

Table 47: Results of Contingency Table Analyses Relating Duration of Residence on Upper Cape Cod to Risk of Death from Lung Cancer--Data Obtained by Informant Interview for Subjects who Met the "10+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of Life Excluded).

Table 48: Results of Contingency Table Analyses Relating Duration of Residence on Upper Cape Cod to Risk of Death from Lung Cancer--Data Obtained by Informant Interview for Subjects who Met the "20+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of Life Excluded).

Table 49: Results of Contingency Table Analyses Relating Duration of Residence on Upper Cape Cod to Risk of Death from Leukemia--Data Obtained by Informant Interview for Subjects who Met the "5+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of Life Excluded).

Table 50: Results of Contingency Table Analyses Relating Duration of Residence on Upper Cape Cod to Risk of Death from Leukemia--Data Obtained by Informant Interview for Subjects who Met the "10+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of Life Excluded).

Table 51: Results of Contingency Table Analyses Relating Exposure to the Southern Geographic Grouping of Sites to Risk of Death from Lung Cancer--Data Obtained by Informant Interview for Subjects who Met the "10+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of Life Excluded).

Table 52: Results of Contingency Table Analyses Relating Exposure to the Southern Geographic Grouping of Sites to Risk of Death from Lung Cancer--Data Obtained by Informant Interview for Subjects who Met the "20+ Years" Residence Requirement (Residential History Accrued During Last 20 Years of Life Excluded).

Table 53: Results of Contingency Table Analyses Relating Exposure to the Central Geographic Grouping of Sites to Risk of Death from Lung Cancer--Data Obtained by Informant Interview for Subjects who Met the "10+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of Life Excluded).

Table 54: Results of Contingency Table Analyses Relating Exposure to the Central Geographic Grouping of Sites to Risk of Death from Lung Cancer--Data Obtained by Informant Interview for Subjects who Met the "20+ Years" Residence Requirement (Residential History Accrued During Last 20 Years of Life Excluded).

Table 55: Results of Contingency Table Analyses Relating Exposure to the Northern Geographic Grouping of Sites to Risk of Death from Lung Cancer--Data Obtained by Informant Interview for Subjects who Met the "10+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of Life Excluded).

TABLE OF CONTENTS (CONT.)

Table 56: Results of Contingency Table Analyses Relating Exposure to the Northern Geographic Grouping of Sites to Risk of Death from Lung Cancer--Data Obtained by Informant Interview for Subjects who Met the "20+ Years" Residence Requirement (Residential History Accrued During Last 20 Years of Life Excluded).

Table 57: Results of Contingency Table Analyses Relating Exposure to the MMR to Risk of Death from Leukemia--Data Obtained by Informant Interview for Subjects who Met the "5+ Years" Residence Requirement (Residential History Accrued During Last 5 Years of Life Excluded).

Table 58: Results of Contingency Table Analyses Relating Exposure to the MMR to Risk of Death from Leukemia--Data Obtained by Informant Interview for Subjects who Met the "10+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of Life Excluded).

Table 59: Number of Matched Pairs Among Eligible Lung Cancer Cases and Controls After Imposition of the Residence Restrictions for Case-Control Analyses.

Table 60: Number of Matched Pairs Among Eligible Leukemia Cases and Controls After Imposition of the Residence Restrictions for Case-Control Analyses.

TABLE OF CONTENTS (CONT.)

LIST OF APPENDICES

Appendix I: Introductory letter to informant

Appendix II: Interview form

Appendix III: Maps illustrating the location of all eligible Upper Cape residences. Three maps for each town:

1. Residences of 1969-1978 Lung Cancer cases and controls
2. Residences of 1979-1985 Lung Cancer cases and controls
3. Residences of 1969-1985 Leukemia cases and controls

Appendix IV: Abbreviations

EXECUTIVE SUMMARY

The Massachusetts Department of Public Health (MDPH) conducted a population-based investigation of female lung cancer deaths and male and female leukemia deaths that occurred among the residents of five Massachusetts towns on Cape Cod during the years 1969 through 1985. The towns included in the investigation were Barnstable, Bourne, Falmouth, Mashpee, and Sandwich. Together these towns constitute an area denoted in this report as the Upper Cape. The study had two objectives: (1) To determine the effect of population in-migration on reported standardized mortality ratios for the Upper Cape; and (2) To determine if people who died of lung cancer and leukemia between 1969 and 1985 lived near areas of air and groundwater contamination, as estimated by duration and location of Upper Cape residence.

The discovery of excess cancer mortality on the Upper Cape, particularly of lung cancer and leukemia, and of hazardous waste disposal activities on the Upper Cape that may have led to air and groundwater contamination, raised concerns in the communities that the environmental contamination may have contributed to the observed cancer excess. In partial response to the concerns, the MDPH designed an epidemiologic survey to obtain residential histories for the lung cancer and leukemia decedents and a control group. MDPH is committed to conducting a comprehensive epidemiologic study of cancer in the future, and the present study was carried out to begin the MDPH investigation of the possible relationship between the Upper Cape environment and the occurrence of cancer.

Results from this study indicated that there had been excess lung cancer and leukemia mortality among the long-term Upper Cape residents. Lung cancer was significantly elevated for both time periods examined, 1969-78 and 1979-1985 (SMR=1.54 and SMR=1.28, respectively). Mortality from leukemia was significantly elevated for the long-term residents who died between 1979 and 1985 (SMR=1.35). For the Upper Cape residents who died prior to 1979, mortality from leukemia was elevated only for short-term residents (SMR=3.14). These results generally failed to support the hypothesis that the observed cancer mortality rates have been significantly influenced by the cancer experience of new Upper Cape residents.

Interviews were successfully completed for approximately 86 percent (n = 177) of lung cancer informants. Of those, 71 percent (n = 126) were characterized as long-term residents. Approximately 76 percent (n = 87) of leukemia informants were successfully interviewed and 82 percent (n = 71) classified as long-term residents. Case-control analyses were carried out but the results could not be meaningfully interpreted because of the limitations in the design of this part of the study.

Nevertheless, the data pertaining to location of residences are informative in that it is clear that, in order for deaths from lung cancer and leukemia to have been caused by exposure at the residence to air and

groundwater contaminants released from identified sources, these contaminants would need to have migrated at significant levels from their sources to the residences of the cases. Thus, based on our findings regarding the proximity of residences to areas of known or suspected environmental contamination, we conclude that: 1) For lung cancer to have been caused by exposure at the residence to air contaminants from the MMR, air contaminants that were capable of causing cancer would likely need to have been carried by the wind at significant levels at least two miles to reach the residences of lung cancer cases. For some sites on the MMR, the contaminants would need to have carried at least four or five miles to reach the residences of the cancer cases. Only two lung cancer cases had ever resided within one mile of any of the sources of air contamination on the MMR. 2) For leukemia to have been caused by exposure at the residence to groundwater contaminants from the MMR or the Mashpee landfill area, chemicals that were capable of causing cancer would likely need to have contaminated the groundwater in areas not yet identified as contaminated, since no leukemia cases were found to have ever resided within any area of known groundwater contamination. Only three leukemia cases had ever resided within one mile of the boundary of the MMR and mapping results did not suggest clustering of cases. The number of leukemia cases potentially exposed to PAVE PAWS emissions was low and no determination regarding the risk of leukemia from exposure could be made. The relationship between leukemia and other sites, such as some selected cranberry bogs and golf courses and the PCE contamination of some parts of the Sandwich municipal water supply, was also examined. No clustering of cases around these sites was suggested by the mapping results. Further analysis of environmental data regarding these sites may be helpful in establishing the potential for adverse environmental exposures.

It is not possible from this investigation to conclude if exposure actually occurred at any of the Upper Cape residences of the lung cancer and leukemia cases. However, the data do not rule out the possibility that lung cancer and leukemia cases were exposed to environmental contaminants.

The Phase I investigation was limited in scope and intended to be exploratory in nature. The limitations in scope included: 1) the use of mortality data instead of incidence data; 2) only two types of cancer were studied; 3) a selected list of environmental sites was evaluated; 4) proxy measures of environmental exposures were used; and 5) other risk factors for the cancers under study could not be accounted for in the analysis. The results of the Phase I investigation, however, did suggest that cancer mortality was elevated in the long-term Upper Cape residents and the proximity of the residences to areas of environmental contamination was identified. The information gained from this investigation provides the rationale for conducting a Phase II study based on the need to better establish the extent of environmental exposure among the long-term residents through a more intensive case-control study of cancer incidence for several different cancer types.

INTRODUCTION

I. PURPOSE

The study described in this report represents the first phase of the response of the Massachusetts Department of Public Health (MDPH) to concern over elevated cancer mortality rates in the Massachusetts towns of Barnstable, Bourne, Falmouth, Mashpee, and Sandwich. A primary goal of this particular investigation was to determine whether lung cancer and leukemia mortality rates were elevated among long-term residents of the five towns. Also of interest were hypothesized relationships between death from these two causes and residence near 1) various sites on the Massachusetts Military Reserve (MMR), 2) the Canal Electric Company, and 3) the Mashpee landfill.

II. BACKGROUND

A. The Upper Cape

The setting for this investigation was the upper portion of Cape Cod, Massachusetts, a 212-square-mile area (1980 population = 80,839) encompassing the towns of Barnstable, Bourne, Falmouth, Mashpee, and Sandwich (Figure 1). The area will be referred to as "the Upper Cape" in this document.

All of the Upper Cape towns have undergone significant population growth since at least 1960.[1] As illustrated in Table 1, which shows the percent increase in total population for each of the five towns between 1970 and 1980, much of this growth has occurred in the "over 65" age category. The total increase for the five towns combined was approximately 47 percent, compared to a 0.8 percent increase experienced by the state as a whole during the same period.

B. History of the Problem

Interest in cancer mortality on the Upper Cape was first expressed by Massachusetts Representative Peter Morin in February of 1985 on behalf of concerned citizens in his district. The communities of particular interest were Bourne, Falmouth, and Sandwich.

Each of these towns abuts the MMR--a 20,000-acre multipurpose military training installation which began operation in 1936. The northern seventy percent of the MMR encompasses the range, maneuver, and impact area of Fort Edwards. The U.S. Coast Guard Transmitter Facility and Cape Cod Air Force Station (PAVE PAWS, an acronym for the Precision Acquisition Vehicle Entry - Phased Array Warning System) are located in this portion of the installation.[2]

Over the years, the U.S. Army, Navy, Air Force, Army National Guard, and Air National Guard have conducted training activities on the base. Although the Navy no longer uses the site, the other

branches of the military continue to train personnel there, and the U.S. Coast Guard launches search and rescue missions from the base. It is also the home of the Massachusetts National Cemetery.[2]

It was suspected that there might be some connection between past hazardous waste disposal activities on the MMR and excess cancer mortality on the Upper Cape. Furthermore, the possible environmental impact of planned base restoration and expansion of operations at the facility concerned area residents.

In September, 1985, the MDPH took a first step in addressing the concerns of the Upper Cape towns and released a report on morbidity and mortality in Bourne, Falmouth, Sandwich, and a fourth community, Mashpee.[3] Included in the report were data pertaining to cancer mortality for the years 1979-1983, cancer incidence for 1982 and 1983, and the occurrence of selected adverse reproductive outcomes for 1974 through 1983. Results indicated that, after adjusting for age, mortality was elevated for some types of cancer (e.g., colorectal, lung, pancreatic, and prostate) and for all cancer types combined, but no consistent trends across sex or community were observed.

This report was followed in October by an update which presented statistics on cancer mortality for two earlier time periods, 1969-1973 and 1974-1978.[4] Findings were similar to those reported for the 1979-1983 period, particularly for lung cancer

and leukemia. With respect to these two causes of death, mortality was elevated in most of the towns during at least two of the three five-year periods for which the data had been reviewed (Tables 2-5). This MDPH report recommended that residential histories be collected for Falmouth females and raised the possibility of a retrospective study of cancer mortality on the Upper Cape.

III. EXISTING ENVIRONMENTAL DATA

A. General Upper Cape Environment

The geology of the Upper Cape is a major factor contributing to the susceptibility of its drinking water supply to contamination. The soil, which was deposited by glaciers, is comprised mainly of sand, along with lesser amounts of silt, clay, and gravel. The composition of the soil makes it highly permeable to rainwater so that surface water runoff is minimal. Consequently, chemical contaminants released into the ground are likely to end up in underground aquifers as constituents of groundwater.

Also important is the fact that the Upper Cape's groundwater has been designated a "sole source unconfined aquifer" by the U.S. Environmental Protection Agency. This means that there are no physical barriers to groundwater movement throughout the area.

The water table ranges from 0 to 100 feet beneath the land surface. The groundwater extends down to impenetrable bedrock located from 80 to 900 feet below sea level. Furthermore, the MMR is situated over the highest groundwater elevation on the Upper Cape. The implication of this fact, along with the previously discussed geological features, is that groundwater flows out in all directions from a point location in the northcentral area of the base. Thus, contaminants in groundwater may be accessible to the many municipal and private wells that tap the aquifer for drinking water.

B. Water Data

An extensive amount of data pertaining to the impact on water quality of contaminants originating both on and off the MMR has been accumulated. The sources of this information include the studies conducted by (a) the firm of Metcalf and Eddy,[5] (b) Weston Consultants,[6] (c) the U.S. Geological Survey (USGS),[7] (d) the Massachusetts Department of Environmental Quality and Engineering, (e) the Barnstable County Health Department, (f) the U.S. Air Force, and (g) E.C. Jordan Co. Major findings of these investigations, as summarized in a memorandum prepared by MDPH in March, 1986,[8] are presented below. The principal sites of potential water and air contamination on the Upper Cape identified by the studies are displayed in Table 6. The locations of these sites are shown in Figure 2.

1. Metcalf and Eddy Report

The U.S. Air Force, as part of its Installation Restoration Program (IRP) for the MMR, contracted with the consulting firm of Metcalf and Eddy in 1983 to identify sites on the base where the potential existed for environmental contamination and from which migration of contaminants was likely to occur in the future.[5]

A review of MMR records revealed that the following six sites had high potential for groundwater contamination, due to the presence of chemical wastes: 1) the current fire training area; 2) the former fire training area; 3) the base landfill, 4) the aviation fuel test dump site; 5) the railyard fuel pumping station; and, 6) the nondestructive inspection laboratory. The data indicated that large quantities of aviation fuel, engine oil, and solvents, along with lesser amounts of transformer oil, herbicides, hydraulic fluid, formaldehyde, and paint may have existed on the sites since the 1950's.

The six sites were ranked according to a scheme based on four aspects of hazard potential: 1) possible receptors of the contaminant; 2) characteristics and quantity of wastes; 3) potential for waste migration; and, 4) quality of waste management practices. The fire training areas located on the southern end of the MMR and the base landfill area to the southeast ranked highest on this scale.

The Metcalf-Eddy report also revealed that the potential for migration of groundwater contaminants outside the boundaries of the base. In particular, it was observed that the MMR landfill was located about 3000 feet from privately owned land and that the MMR firefighting training area was situated less than one mile from the nearest downgradient drinking water supply well, the Ashumet well serving the town of Falmouth. Other factors contributing to the threat of contaminant migration off base are the permeability of the soil and the proximity of the sites to the underlying aquifer.

2. Weston Report

Another phase of the Base Installation Restoration Program was initiated to confirm and quantify the contamination problem. Towards this end, Weston consultants attempted to determine the direction and rate of groundwater flow.[6] Data published by this group and the U.S. Geological Survey in October of 1985 indicated that water flows in all directions from a point located in the north-central part of the MMR (Figure 3) at a rate of about one to two feet per day, depending upon the density of the contaminants.

Weston consultants also detected the presence of solvents at some of the six sites which had been identified by Metcalf and Eddy.

Both the U.S. Environmental Protection Agency (EPA) and the Massachusetts Department of Environmental Quality Engineering (DEQE) observed that the Weston group had failed to fully identify the source of the groundwater contaminants or determine the extent of soil and groundwater contamination on or off the base.[9] In other words, the exposure potential of Upper Cape residents had not yet been established.

3. U.S. Geological Survey Studies

Other environmental studies have been conducted independently of the Base Installation Restoration Program. The U.S. Geological Survey studies (USGS),[10] for example, developed out of concern for groundwater contamination from waste-water treatment plants employing rapid infiltration techniques. The sewage treatment plant at the MMR has employed this technique for approximately 45 years. The study documented the presence of a groundwater plume approximately two miles long and one-half mile wide, apparently emanating from MMR sources in the southern portion of the base. The plume was found to be traveling at a rate of about 0.8 to 2.3 feet per day in a south-southwesterly direction.[10]

Chemical constituents of the plume included high concentrations of detergents and nitrates, along with two volatile organic compounds (VOCs), trichloroethylene (TCE)

and tetrachlorethylene (PCE). The distribution of these organics suggested an origin similar to that of the detergents and indicated that they had probably entered the plume within the last ten to fifteen years.

VOCs have also been detected in wells on the MMR, but the levels of these compounds in the well did not exceed the Environmental Protection Agency SNARLS (Suggested No Adverse Response Levels).[5]

The Ashumet well, a Falmouth municipal well constructed in 1976, was closed by the DEQE in 1979, because detergent concentrations in the well exceeded recommended limits (0.5 mg/l). VOCs were not found at that time, despite the close proximity of the Ashumet well to the VOC contaminated wells on the MMR.

By the early 1980's, VOCs were detectable in the Ashumet well. Data collected by the U.S. Geological Survey in 1983 indicated that the highest concentrations of these compounds were still upgradient from the well, and that their concentration in the well would continue to increase for several years.[10] The data also suggested that, while the center of the detergent zone of the plume had moved past the well, it would take between fifteen and thirty years after the source of the contamination had been eliminated for the tail of the contaminant plume to pass the well.

4. U.S. Air Force Sampling

The evidence of off-base drinking water contamination prompted the U.S. Air Force to sample private wells in the Ashumet Valley area of Falmouth. Approximately 200 wells were tested in 1985, and about 40 were found to contain detectable levels (up to 230 ppb total VOCs) of VOCs.[7,11-13]

5. E.C. Jordan Monitoring

Private wells in Briarwood, a section of Mashpee located immediately south of the John's Pond Dump and a former fire training area on the MMR (Figure 2), were sampled by the Barnstable County Health and Environmental Department in 1986, and later by the E.C. Jordan Co. for the Department of Defense.[14] TCE and PCE were detected in some of these wells.

The Department of Defense is currently involved in an evaluation of the more than forty sites on the MMR which are now recognized as potential sources of groundwater contamination. Data thus far available suggests that chemicals from one or more sites on the MMR have contaminated the groundwater in areas south of the MMR and that chemicals such as TCE and PCE have made their way into the private wells of homes in Falmouth and Mashpee.[7,11-13]

6. Barnstable County Health and Environmental Department Studies

Although sources of chemical contamination on the MMR have received the most attention, town waste disposal operations and local industrial activity may also have adversely affected water supplies on the Upper Cape.

The Mashpee landfill (Figure 4), for example, is suspected of contributing to the contamination of drinking water supplies in the vicinity of Asher's Path. The Barnstable County Health and Environmental Department detected 1,1,1,-trichloroethane (TCEA) and other VOCs at concentrations up to 810 ppb in this area of Mashpee in late 1985. This level of contamination exceeds the EPA maximum for drinking water.[15]

In 1986, the Barnstable County Health and Environmental Department sampled additional homes with private wells. The contamination has been confirmed in a number of homes within a half-mile area south of the landfill,[15] and efforts to characterize the nature and extent of the groundwater contamination continue.

Not all of the available evidence points to the Mashpee landfill as the source of the VOCs in Mashpee wells; results of environmental modeling studies conducted by Weston and Sampson in 1987 imply that the main contaminant plume may have

originated from a site just east of the landfill.[16] Whatever the source, the contaminated groundwater appears to be flowing in a south-southeasterly direction towards the Mashpee River.

Municipal water supplies in Barnstable, Bourne, Falmouth, Mashpee, and Sandwich were recently sampled for twenty-one VOC's by the Barnstable County Health and Environmental Department. The data revealed that the water supplies, in general, are not contaminated at levels that would be expected to cause adverse health effects. Two particular findings were noted: PCEs in Sandwich and trihalomethanes in certain areas served by the Falmouth system.[17]

In 1980, PCE was detected in some areas of Sandwich, and concentrations exceeded the maximum levels set by the EPA for drinking water.[18] The presence of this chemical in drinking water has been linked to the use of vinyl-lined asbestos cement water mains, approximately fifty miles of which were installed between 1969 and 1979. PCE is a solvent used in the manufacturing process which, for a period of time, remains in the pipes and leaches into the water flowing through them.[18] Efforts are currently underway to reduce the level of PCE in the water to within the recommended level.

In 1987, trihalomethanes, chemicals formed when drinking water supplies are treated with chlorine, were detected in

Falmouth, at concentrations of about 20 mg/l.[18] The EPA recommended maximum is 100 mg/l.

7. Other Potential Groundwater Sources

Various industries have thrived on the Upper Cape over the years, including the sheep, cranberry, and glass industries. Environmental data regarding these industries on the Upper Cape is very limited; however, the use of pesticides and other chemicals generally associated with the industries may have affected the Upper Cape environment.

A number of hazardous waste sites, currently in various stages of confirmation and remediation, have been identified in the five Upper Cape towns by the DEQE.[19] The known or suspected sources of these sites have included small chemical spills, service station gasoline tank leaks, and containers of unspecified wastes.

C. Air Data

Automobiles, the Canal Electric power plant, and the MMR power plant have all contributed to air pollution on the Upper Cape. Various activities which have occurred over the years on the MMR have also been implicated as sources of airborne contaminants. Specifically, chemicals, artillery shell propellants, and vegetation have been burned; also, fuels and solvents have been dumped onto the ground and unknown quantities may have volatilized.

Very little air monitoring has taken place, and few details are available regarding the nature, amounts, or dispersion of the chemicals emitted from most sources. The following discussion summarizes information regarding the identified sources of air pollution.

1. Power Plants

Canal Electric is an oil fired plant located in Sandwich that began generating power 1968. Available air monitoring data have shown that, although the plant emits in excess of 200 tons of SO_2 per year, air quality standards for SO_2 and particulates have not been violated. Nevertheless, "sootfalls", episodes of oily particulates falling to the ground, have been recorded.[20]

The highest average concentrations of SO_2 in the vicinity of the plant have been associated with winds from the westsouthwest through northwest--an observation made whether the air monitors were situated upwind or downwind from the plant. This phenomenon has been explained by an influx of air containing large amounts of SO_2 emanating from sources off the Cape.[21]

While SO_2 is not a carcinogen, the modeling of SO_2 emissions could provide information about the dispersion of as yet unidentified carcinogenic chemicals also emitted from the stack. Results of a number of modeling studies have

indicated that the areas affected by the highest concentrations of emissions are over water, approximately three miles northeast of the plant. This pattern of dispersion is related to the height of the stack and the direction of the prevailing winds, which are from the southwest through northwest approximately forty-three percent of the year.[22]

The Otis power plant, located on the MMR, is the only other major power plant on the Upper Cape. Emissions from the Canal Electric plant (about 250 tons SO_2 per year) far exceed those associate with Otis plant's stack (usually less than 10 tons SO_2 per year). The highest concentrations of pollutants from the latter occur within a quarter mile of the plant, the concentration falling off rapidly as distance from the plant increases.[21]

The other major causes of air pollution on the Upper Cape; i.e., burning of propellant bags and vegetation, fire training, and fuel dumping are MMR activities. As such, they constitute ground sources, because emissions are not dispersed from a stack.

2. Propellant Bag Burning Sites

Propellant bags contain measured quantities of chemicals used to propel mortar and artillery shells. The amount of propellant used with each shell depends upon the distance the shell is to be sent. Unused quantities of propellant

are disposed of by burning at the firing sites, some of which are within one mile of residential areas.

Approximately 500 to 700 pounds of propellant are currently burned yearly, and unknown quantities have been burned since the 1940's. The compound 2,4-dinitrotoluene, a suspected carcinogen, constitutes approximately 10 percent of the propellant mixture. Some of this compound may be released into the air and/or soil when the bags are burned.[23,24] Consequently, the hypothesis that the population residing near the firing sites is being exposed to carcinogens emitted through propellant bag burning is plausible. Modeling and/or monitoring activities designed to evaluate this hypothesis are planned by the Department of Defense, in cooperation with the DEQE.

Although inhalation is the most likely route of human exposure to the products of propellant bag burning, the Department of Defense is currently testing soil in the area of the burn sites in an effort to determine the potential for groundwater contamination by residue from the burns.

3. Fire Training Sites

Until recently, fire training, another activity which may have contributed to the contamination of both water and air, was conducted by the MMR fire department at sites located at the southern end of the base (Figure 2). Aviation fuel,

waste oils, solvents, and transformer oils were burned at the site, in quantities ranging from 50 to 500 gallons per training session. Reportedly, up to 16 training sessions per year took place between the late 1940's and 1985.[2]

4. Fuel Dump Sites

Between 1955 and 1969, fuel dump valves on aircraft were tested at a site located at the southeastern end of the MMR (Figure 2). It is estimated that a total of from one to six million gallons of aviation fuel were dumped at the site in the process of testing the valves. While the dumping of organic chemicals onto the ground might have had a greater potential for affecting water vs. air quality, air pollution by the fuel might have occurred through volatilization.

D. Other Environmental Data

The PAVE PAWS radar installation is another site on the MMR which has been suspected of contributing to the Upper Cape's cancer burden. PAVE PAWS is a fixed base solid-state phased array warning system located in the northwestern part of the base. The facility has been used by the U.S. Air Force since 1978 to detect sea launched ballistic missiles.[3]

In September of 1986, the U.S. Air Force, with the cooperation of the MDPH, conducted a Radio Frequency Radiation (RFR) survey at the PAVE PAWS site and in sixteen locations in Bourne, Mashpee,

and Sandwich.[25] Testing sites were chosen so that the maximum levels of RFR to which individuals in those areas were being exposed could be determined. The closest testing site off the MMR was located 1.2 miles away in Sandwich, and the farthest, 8.8 miles away in Mashpee.

Radiation levels off-site were found to be highest at locations which were in the direct line of sight of PAVE PAWS. This finding is consistent with evidence indicating that RFR is greatly attenuated by trees, hills, and other structures.[26] Results also revealed that maximum exposure levels were below proposed guidelines set by the EPA and less than 1/1,000 of the Massachusetts regulatory exposure limit established by the MDPH.[27]

IV. SCOPE OF THE PROJECT

The fact that environmental contamination exists in an area where elevated cancer rates have been observed does not constitute sufficient evidence that the two phenomena are related. The reasoning for hypothesizing such a relationship is derived from toxicologic data and from studies suggesting associations between cancer occurrence and residential exposure to environmental agents similar to those of concern on the Upper Cape. Trichloroethylene (TCE), tetrachlorethylene (PCE), and 2,4-dinitrotoluene, chemicals found in the Upper Cape environment, have been classified as carcinogens.[23,24,28] Furthermore, an association was reported in Woburn, Massachusetts between the incidence of childhood leukemia and

the distribution of drinking water form municipal wells contaminated with TCE and other volatile organic compounds.[29]

Whereas the MDPH was committed to conducting a comprehensive epidemiologic study of cancer in the future, the present study was designed to begin its investigation of the possible relationship between the Upper Cape environment and the occurrence of cancer. Lung cancer and leukemia were singled out from the other cancer types for the following reasons: 1) a number of Upper Cape towns had experienced consistent elevations in mortality from these two diseases; and, 2) the literature generally supports a connection between the identified air and groundwater contaminants and the occurrence of these cancer types.[30-35]

The decision to conduct a study of mortality vs. incidence was made for two reasons. First, the use of mortality data can greatly simplify the task of case ascertainment and control selection, because deaths are readily accessible vital statistics. Second, the average five-year survival rate for lung cancer is low, so that, at least for this disease, little would be gained by expending the extra effort needed to collect incidence data.

V. OBJECTIVES OF THE STUDY

A. Recalculation of the Standardized Mortality Ratios (SMRs)

A simple and easily tested hypothesis which might be proposed to explain the elevated cancer mortality rates on Upper Cape Cod

involves the great increase in the five-town population which has occurred recently. When such a large number of people move into an area, the possibility exists that the observed cancer rates for a community may have been influenced by the cancer experience of the new residents. Thus, one objective of this investigation has been to determine to what extent the elevated cancer rates reflect the experience of the long-term portion of the population. Specifically, we sought to compare the age-standardized lung cancer and leukemia mortality rates of both short-term and long-term upper Cape Cod residents to those of the state as a whole.

B. Environmental Analyses

The environmental data accumulated thus far regarding the quality of the air and water on the Upper Cape suggests that contamination by carcinogens has occurred in the past and is probably continuing at some locations. A second plausible explanation for the elevated lung cancer and leukemia rates, then, is that the documented air and water pollution may be the cause. Hence, a second major objective of this study was to consider the location of case residences in relation to identified sources of environmental contamination.

The remainder of this report is divided into the following areas of discussion:

1. The methods employed to accomplish the study objectives;

2. The upon which conclusions have been based; and,

3. The conclusions drawn from the data, taking into account the various limitations inherent in the study's design.

METHODS

I. STUDY DESIGN

The objectives of this investigation required the collection of residential histories for the cancer cases and for a group of "controls" equal in size to the case group. Data analysis involved 1) the calculation of Standardized Mortality Ratios (SMRs) which took into account the instability of the Upper Cape Cod population and 2) consideration of the distribution of mapped case and control residences relative to identified sources of environmental contamination.

Since the study design was conducive to pursuing simple case-control analyses, several hypotheses regarding the relationship between lung cancer and leukemia mortality and location duration of residence on Upper Cape Cod.

For the case-control analyses, exposure was operationalized in three ways as follows: 1) the distance in miles (measured to the nearest half mile) between an exposure source (Table 6) and the address nearest to that source that a subject had occupied during the period of interest; 2) the duration in years (measured to the nearest year), of a subject's residence on the Upper Cape, within the time period of interest; and 3) the value of an exposure score which combined the distances from exposure sources of all residences occupied during the time period of interest with the

associated durations of residence.

II. POPULATION

Two populations were of interest in this study, one corresponding to each of the two causes of death (lung cancer and leukemia) under investigation. For the analyses which concerned lung cancer, the population consisted of all females who had died as permanent residents of the towns of Barnstable, Bourne, Falmouth, Mashpee, and Sandwich, between January 1, 1969 and December 31, 1985. For the leukemia investigation, the population consisted of all males and females who died as permanent residents of the five towns between January 1, 1969 and December 31, 1985.

III. SAMPLING FRAME

A. Cases

Potential cases were selected from a computer printout listing the names, ages, sexes, dates of death, death certificate numbers, International Classification of Diseases (ICD) codes, and codes for town of residence and town of occurrence of all permanent residents of the five Upper Cape towns who had died of cancer between January 1, 1969 and December 31, 1985.

The printout was prepared by MDPH's Division of Health Statistics and Research from computerized files created

using information recorded on death certificates. Lung cancer and leukemia deaths were identified by ICD codes (162.1-162.9 for lung cancer and 204-208 for leukemia).[36]

All individuals so identified were selected as potential cases. Eligibility of selected subjects was subsequently determined by their residential histories.

B. Controls

Controls were randomly selected from among Upper Cape Cod residents who had died of conditions other than leukemia and lung cancer between January 1, 1969 and December 31, 1985. Sampling was carried out using the computerized mortality files maintained by the MDPH's Division of Health Statistics and Research.

Since there were considerably more potential controls than potential cases, the Division of Health Statistics and Research produced two printouts for control selection--one a 25 percent random sample of all deaths of five-town area residents (from which lung cancer and leukemia cases had to be stricken) and another that listed all deaths not attributable to either lung cancer or leukemia.

Controls were matched to cases on year of death (within one year), age (within one year) and sex. To facilitate this process, entries on both lists were arranged by year of

death, by sex within each year of death, and finally, by age within each sex.

Most controls were selected from the list representing the 25 percent sample; use of the more comprehensive list was reserved mainly for the matching of very young or very old cases, for whom the 25 percent sample did not always provide a suitable control.

IV. DETERMINATION OF ELIGIBILITY

The residential history of each case and control identified from the computerized MDPH mortality file determined his or her eligibility for inclusion in the data analyses as follows:

A. SMR Calculation

All subjects who had died of leukemia or lung cancer between January 1, 1969 and December 31, 1985 were eligible for inclusion in this phase of the study as were all of the controls selected to match them.

B. Environmental Analyses

1. Establishment of a Time Window of Relevant Exposure

Several rules were employed for defining an eligible subject and for determining the extent to which each

eligible subject might have been exposed to cancer causing substances. These rules were based upon conventional notions of the mode and time of action of chemicals in the natural history of the cancers of interest.

It was assumed, for example, that air and groundwater contaminants acted as initiating agents in cancer causation. Initiators are factors which act early in the natural history of a disease, and, in cancer causation, a long lag-time usually intervenes between the initiating event (cellular change) and death. This period is termed the "empirical induction time" for the purposes of this study.

The appropriateness of the induction time assumption affects the accuracy of the results of the case-control analyses and conclusions that might be drawn from consideration of location of residence. With respect to the case-control analyses, the use of an inaccurate assumption would result in what is called non-differential misclassification of subjects and introduce bias into the measurement of the strength of the association between the putative cause (exposure) and effect (death from cancer). With respect to location of residence, an inaccurate induction time assumption would result in the mapping of residences which had been occupied by subjects during a period of

time when exposures could not have been related to causation of disease.

The practical implication of assuming a particular empirical induction time is the establishment of a "time window of relevant exposure" which corresponds to the range (difference between the maximum and the minimum) of the empirical induction time assumed. For example, if a reasonable minimum for the empirical induction time is ten years (i.e., the lag-time between action of the initiator and death from the particular type of cancer could not be shorter than ten years), and a reasonable maximum is forty-five years (i.e., the lag-time between the action of the initiator and death from the particular type of cancer could not have been longer than forty-five years), then the time window of relevant exposure is "ten to forty-five years."

Once established, this window can be used to define both an eligible subject and a period of time in an eligible subject's life during which his exposure experience could be considered relevant to the causation of the disease under study. Employing the time window suggested above implies that subjects who were exposed only during the period within ten years of death or prior to a date forty-five years before death would not be included in analyses. Similarly, any exposure history of included subjects which occurred

outside of the time window would not be counted.

The following facts made the choice of an empirical induction time difficult in this study: 1) the empirical induction time varies with the causal factor, such that, for any cancer type, there are a number of empirical induction times; 2) there is a certain amount of variability in the empirical induction time, even when there is a single well-defined exposure of interest; and 3) the nature of the chemical contamination on the Upper Cape was not fully known at the outset of the study.

In consideration of our uncertainty regarding the lengths of the empirical induction times for lung cancer and leukemia, we estimated the magnitude of the effect between each independent and dependent variable twice--employing a different empirical induction time assumption, and thus a different time window, in each instance.

For lung cancer cases (and their controls), the two time windows established in this investigation were "ten to forty-five years" and "twenty to forty-five years." The lower boundary, corresponding to the minimal induction time, was varied, because, depending upon the particular exposure, a reasonable minimum empirical induction time for lung cancer might be as short as ten years or as

long as twenty years.[37] We set the upper limit of both time windows employed for the lung cancer series at forty-five years, because this figure 1) corresponds to a reasonable maximum empirical induction time for lung cancer, and 2) closely approximates the number of years which could have elapsed between the opening of the MMR in 1936 and the time of death, in 1985, of the most recently deceased subject.

Both the minimum and maximum induction times for leukemia, although variable, may be somewhat shorter than analogous values for lung cancer.[37,38] Thus, we set both limits of the two time windows lower for this cause of death. Here again, only the lower limit was varied, yielding the following two time windows: "five to twenty-five years," "ten to twenty-five years."

2. Definition of an Eligible Residence

One of the ramifications of establishing a time window of relevant exposure was that residences, and any associated duration of residence, that had been occupied by a subject during times not encompassed by the time window were not counted in the assessment of the subject's exposure status. Additionally, some residences that did qualify on this basis were excluded, if they had not been occupied by subjects for at least three consecutive months.

This rule followed from the assumption that exposure had to have occurred over some minimum period of time for it to have been relevant to cancer initiation.

The specific requirement of three months was used in order to 1) permit inclusion of subjects who had been full summer residents (but not year-round residents) during the period corresponding to the time window of relevant exposure and 2) allow exclusion of those cases and controls who had merely vacationed, usually for one or two weeks per year, on the Upper Cape during the relevant time period.

3. Minimum Residence Requirements

Simultaneous application of the principle of a time window of relevant exposure and the definition of an eligible residence engendered two eligibility requirements, referred to in this report as "minimum residence requirements," for each cause of death.

Minimum residence requirements were established for the lung cancer series as follows: 1) a minimum of three consecutive months of residence on the Upper Cape beginning no more recently than ten years prior to death (10+ years residence requirement); and, 2) a minimum of three consecutive months of residence on the Upper Cape beginning no more recently than twenty years prior to

death (20+ years residence requirement).

Minimum residence requirements imposed on the leukemia series were established as follows: 1) a minimum of three consecutive months of residence on the Upper Cape beginning no more recently than five years prior to death (5+ years residence requirement); and, 2) a minimum of three consecutive months of residence on the Upper Cape beginning no more recently than ten years prior to death (10+ years residence requirement).

4. Exclusion of Residential History Accrued Prior to 1940

Any residential history accrued prior to 1940, regardless of the subject's year of death, was excluded in the assessment of exposure. This rule was imposed, because the exposures of interest were not occurring to any significant extent prior to this date. Thus, inclusion of such an exposure would have resulted in misclassification of subjects and incorporated bias into the measurement of the strength of the association between exposure and death from lung cancer or leukemia.

5. Examples of the Application of the Various Exclusion Rules

One of the independent variables of interest in this investigation was "duration of residence on Upper Cape

Cod." The following examples illustrate how the residential history of a hypothetical individual would have been used to determine both his/her eligibility and exposure status in various environmental analyses relating duration of exposure to death from lung cancer or leukemia.

Example: A case or control had resided on the Upper Cape for forty years dating from January 1, 1936 to his/her death on December 31, 1985.

If this individual was a lung cancer case or control, she would qualify for entry into the environmental analyses according to both of the minimal residence requirements established for this cause of death. She would qualify on the basis of the "10+ years" residence requirement, because she had resided on the Upper Cape for three months prior to the end of 1975. She would qualify on the basis of the "20+ years" residence requirement, because she had resided on the Upper Cape for three months prior to the end of 1965.

Applying the "ten to forty-five years" time window, her duration of residence would be thirty-six years; the other twenty-four years (between 1936 and 1940 and between 1976 and 1985) is considered to have been irrelevant to her risk of lung cancer from exposures related to activities occurring on the Upper Cape. Applying the

"twenty to forty-five years" time window, her duration of residence would be twenty-six years (1940-1965).

Were the individual a leukemia case or control, he/she again would qualify for both analyses. He/She would qualify on the basis of the "5+ years" residence requirement, because he/she had resided on the Upper Cape for three consecutive months prior to the end of 1980, and he/she would qualify on the basis of the "10+ years" residence requirement as explained above.

As a leukemia subject, his/her duration of residence would be fifteen years (1961-1975) employing the narrower time window ("ten to twenty-five years") and twenty years (1961-1980) employing the wider one ("five to twenty-five years").

6. Summary

The eligibility requirements restricting entry of cases (and controls) into the various analyses relating exposure to the Upper Cape Cod environment to risk of death from lung cancer and leukemia are summarized on the next page.

Case-Control Series	Analysis Carried Out	Subject Eligibility Requirements	Residence Eligibility Requirements
Lung Cancer	SMR	-Female -Upper Cape Resident at Time of Death -Died between 1/1/69 and 12/31/85	none
	Environmental	SMR Requirements Plus:	
	10+ Years Residence Requirement	-First Year of Upper Cape Residence at Least 10 Years Pre Death	-Occurred Prior to 10 Years Pre Death -Occurred Since 1940 -Residence Occupied for at Least 3 Consecutive Months
	20+ Years Residence Requirement	-First Year of Upper Cape Residence at Least 20 Years Pre Death	-Occurred Prior to 20 Years Pre Death -Occurred Since 1940 -Residence Occupied for at Least 3 Consecutive Months
Leukemia	SMR	-Upper Cape Resident at Time of Death -Died Between 1/1/69 and 12/31/85	none
	Enviornmental	SMR Requirements Plus:	
	5+ Years Residence Requirement	-First Year of Upper Cape Residence at Least 5 Years Pre Death	-Occurred Prior to 5 Years Pre Death -Occurred Since 25 Prior to Death -Residence Occupied for at Least 3 Consecutive Months
	10+ Years Residence Requirement	-First Year of Upper Cape Residence at Least 10 Years Pre Death	-Occurred Prior to 10 Years Pre Death -Residence Occupied for at Least 3 Consecutive Months

V. DATA COLLECTION

A. Overview

The study's original protocol called for the determination of each subject's residential history through the review of town directories. We found, however, that records were of uneven quality across towns and time periods. Consequently, we decided that, for each subject, a telephone interview with the individual identified on the subject's death certificate as the "informant" or "next of kin" for the deceased would be attempted--the town directories being reserved for use as a supplemental source of information for subjects who had died between 1979 and 1985. Residential histories of subjects from the towns of Bourne and Sandwich who had died between 1969 and 1978 were also obtained both from the town books and from informant interviews; the directories for these towns were easily accessible to MDPH, and it was convenient to trace the small number of subjects from Bourne and Sandwich in this manner.

As data collection proceeded, it became clear that the telephone interviews were superior to the town books in a number of ways; first, the informants could supply more complete information for subjects who had moved from town-to-town within the five towns; second, the informants could identify nearby landmarks or current numbers for houses which had had no numbers at the time the subjects had resided in them;

third, the informants could comment on whether subjects had ever "summered" on the Upper Cape prior to taking up permanent residence there; fourth, informants could supply information about subjects who had never been listed in town directories due to their failure to vote or return census forms; fifth, informants could provide smoking histories; and finally, informants could more accurately provide an estimate of the total duration (beyond the applicable residence requirement) of the subject's residence on the Upper Cape--particularly for long-term residents whose first year of residence in the five towns long preceded the earliest year for which directories were available. Thus, when telephone contact had been made for any given subject, information supplied by the town books was used only to clarify such details as house numbers and to facilitate decision-making with respect to the qualification of a subject who was said to have lived on the Upper Cape "eight or ten" years (in the case of lung cancer victims) or "four or five" years (in the case of leukemia victims).

Histories obtained from town directories were also used in the SMR calculation phase of the study as the exclusive data source for subjects for whom an informant interview could not be completed. Although it was recognized that, for the reasons delineated above, use of this resource might have resulted in the misclassification of some individuals, the major drawback to depending upon the directories was the limited number of years for which they were available--a

problem which posed less of a threat to the validity of the SMR calculations than to the environmental analyses, since for the former purpose, the point was to establish whether each individual had or had not resided in the area for a particular number of years. Since the number of years in question never exceeded twenty, the books were usually considered an adequate resource.

B. Residential Histories--Town Directories

Determination of a subject's residential history from town directories proceeded as follows: The name of a subject who had died in a given year was sought in the book published in that year in the town where, according to the death certificate, the subject had resided at the time of his death. If the subject was not listed in this book, his name was sought in the directories published in the town of his death in the two previous years. It was assumed that a subject whose name did not appear in any of these books had never been listed, and the search was ended. Once a subject's name was found in any book, it was next sought in the book published five years prior to the publication date of the book in which it was found, and so on until the searcher failed to find it. When a name disappeared, it was sought in the books published in the town of death in the two years preceding the publication date of last book searched. Subjects whose names could not be located in three consecutive books were considered lost, and the searcher would next trace the name forward in an

effort to locate the exact year when it was first listed. Books published in some towns in the 1960's lacked alphabetical listings of residents' names. In such instances, each subject's name was sought only at his/her last known address. Names were never sought in books published in towns other than the town listed as the "town of residence" on the subject's death certificate. Thus, residential history accrued in towns other than the town of death was not counted in residential histories obtained from town directories.

C. Residential Histories--Telephone Interviews

1. Identification and Location of Informants

Death certificates for individuals selected from the computer printouts were obtained from the MDPH Registry of Vital Records. The individual identified on the death certificate as the "informant" or "next of kin" was designated the official informant for the study.

Before telephone contact with an informant was attempted, an introductory letter (Appendix I) was mailed to him/her at the address listed on the corresponding subject's death certificate. The letter explained, in general terms, the aims of the study and the method of informant identification. The study's hypothesis was alluded to only in terms of a possible association

between the environment and disease among Cape Cod residents. The letter also assured informants of confidentiality through strict adherence to the letter of relevant laws.

Once the letters had been sent, telephone numbers for informants were sought in current phone directories and/or from New England Telephone Directory Assistance. Since some subjects had died nearly twenty years prior to the study's initiation, this procedure resulted in the identification of telephone numbers for living informants only a small percentage of the time. When numbers for informants could not be obtained from either the phone directory or from Directory Assistance, the last name of both the informant and the subject were traced in the Cape Cod telephone book. In the case of uncommon names, usually all individuals with the same last name as the informant or the subject were called for the purpose of determining whether the persons listed were relatives or friends of the subject. For subjects or informants with more common names, only persons listed in the same village in which the subject or informant had lived were contacted, unless an individual with the same full name as the subject or informant was listed in some other village or town. When these efforts failed to identify a suitable informant, the death certificate was consulted for further information. Sometimes the subject's birthplace was listed; this could

then be used in conjunction with the subject's, the informant's, and the subject's parents' names in attempts to locate relatives. Other death certificate items that sometimes proved useful in locating informants were the names of institutions (e.g. worksites, nursing homes, housing complexes, etc.).

When the informant was not identified on the subject's death certificate as a Cape Cod resident, and when Directory Assistance listed no such individual in the town where the informant supposedly had resided at the time of the subject's death, Directory Assistance was asked for any individual with the informant's last name in the same or nearby towns.

If all of the above-described methods failed to result in the location of an informant, public records at the Barnstable County Registry of Probate were used as a source of names of additional relatives and friends of the subject, or, in some cases, a more recent address or new last name for the original informant. In most cases in which a subject's estate had been probated, at least one friend or relative with a listed telephone number could be found. Sometimes, when a subject was not listed with the Registry, the estate of the spouse or informant had been probated, and perusal of the records of one of these individuals led to the identification of a potential informant.

Whenever any of these efforts led to telephone contact with a friend or relative of the subject who was not the original informant, the aims of the study were explained as they had been in the introductory letter, and the contact was asked if he or she was the person best qualified to provide the information sought. If the contact answered affirmatively and consented to be interviewed, he or she was questioned on the spot. Often, an alternate was suggested by the contact. In such cases, a letter was sent to the suggested individual, and telephone contact was made after several days. In the few instances in which the only available informant had a non-published telephone number, a questionnaire adapted from the interview script was sent to the informant along with the introductory letter, instructions for completing the questionnaire, and a stamped envelope addressed to MDPH. Informants for four lung cancer cases (and 5 controls) and two leukemia cases (and one control) provided residential histories by written questionnaire.

2. Blinding

Since all subjects were dead, most informants were easily kept blind as to whether their deceased friend or family member was a case or a control. The study was well publicized, however, and, because it had been described in the media as a "cancer investigation," some

informants for subjects who had not died of cancer expressed reluctance to participate. In order to ensure maximum participation, interviewers were told that, if an informant cited the subject's cause of death as the reason for refusal, the interviewer should explain that the subject was a control, and that his contribution to the study was important.

Informants for accident, homicide and suicide victims as well as those for subjects who had died of alcoholism or drug abuse, were sent special letters, in addition to the introductory letter, informing them that their friends or family members had been included as controls. This was done in the interest of sensitivity; i.e., it would seem insultingly careless to bother loved ones of such individuals for a study of the relationship between environment and disease.

While it might seem more prudent to exclude accident, suicide, and homicide victims than to proceed as we did, we felt it important to include as many deaths as possible which could not have been caused by environmental exposure in order to counteract the potentially biasing effects of including subjects as controls who had died of diseases which may have been caused by the exposures of interest.

Interviewers were generally blind to the case-control status of the subjects, except in those cases described above in which the informant revealed the cause of death to the interviewer.

Given the nature of the information collected in this study, we consider it unlikely that knowledge of a subject's case-control status and/or the hypothesis under investigation would have threatened the study's validity. More specifically, it is improbable that an informant's recollection of a subject's residential history would be affected by such knowledge.

3. Interview Administration

The interview script (Appendix II) was adapted from one used in a study conducted previously by the MDPH and was designed to obtain, in ten minutes, residential and smoking histories for the subject.

Once the informant had given his/her permission for the interview, he/she was prompted to recall the subject's past by the interviewer's request that he/she verify certain information recorded on the death certificate, namely, the year of the subject's death and the subject's permanent address at the time of his/her death. Next, the informant was asked to approximate the number of years that the subject had resided at the

"death address" or to supply the approximate year when the subject had moved in. The interviewer then asked for each of the subject's previous addresses and the corresponding lengths of residence, until such time as the informant gave an off-Cape location. At this point, the interviewer asked if the subject had ever had any other Cape Cod addresses or history of summer residence and recorded the relevant information.

The remainder of the interview dealt with smoking history and included questions pertaining to the age at which the subject had begun to smoke, whether and when he/she had quit, and the number of packs of cigarettes per day he/she had smoked. Informants who were offspring of subjects tended not to know when their parents had acquired the smoking habit. In such cases, the interviewer would ask the informant to supply a minimum number of years that the subject had smoked, or the number of years that the informant recalled observing the subject smoking.

It was relatively common for an informant to have such limited knowledge of the subject's smoking habits that he/she could not estimate the number of packs per day smoked. In these cases, the interviewer was instructed to ask whether the informant would classify the subject as having been a heavy smoker. We consider the responses to this question to be of limited usefulness,

because, among informants who could provide an estimate, there was little agreement as to how many packs per day constituted "heavy smoking." The question was not asked frequently enough of fully knowledgable informants to formally analyze the validity of this item.

No attempt was made to validate the interview, nor was reliability assessed. Interviewer training sessions did take place. In these sessions, the project manager 1) went over the script with the interviewer, 2) observed the interviewer placing his/her first few calls, and 3) suggested ways to improve the interviewer's technique. Additionally, all scripts submitted by each interviewer were reviewed by the project manager, and clarification by the interviewer and repeat calling were required as necessary.

VI. MEASUREMENT OF EXPOSURE

Conclusions from this investigation relative to exposure of subjects to environmental contamination were based on the following surrogate measures of exposure: 1) proximity of qualifying residences to known or suspected sources of air or water contamination, 2) duration of each "exposed" individual's residence on Upper Cape Cod, and 3) a combination of both variables.

A. Mapping

After review of the residential histories to determine the eligible subjects for the exploration of the environmental hypotheses, all eligible Upper Cape residences were located on enlarged street atlases of the five towns. Each residence was identified by a pin denoting the case/control status and identification number of the subject.

Three sets of six enlarged maps [39] (one per town for Bourne, Falmouth, Mashpee, and Sandwich, two for Barnstable) were prepared as follows: One set of maps was prepared to represent all eligible Upper Cape residences for the 1969-78 lung cancer cases (and controls). Another set represented all residences for the 1979-85 lung cancer cases (and controls). A third set of maps illustrated all eligible Upper Cape residences for the 1969-85 leukemia cases (and controls). Residences for all leukemia subjects were shown on the same set of maps, rather than splitting them into the two decades of death, because the number of subjects was substantially less than the number of lung cancer subjects.

The scale of the maps on which the distance measurements were made was "1 inch = 3/4 mile." The locations of the residences were later plotted on 8½" x 11" maps, but no distance measurements were attempted using these smaller maps. The location of the residences on the enlarged maps, the distance measurements, and the placement of marks

indicating residence locations on the smaller maps were all verified.

B. Distance of Residence from Suspected Sources of Environmental Contamination--Lung Cancer

Some of the suspected sources of environmental contamination which have been identified on the Upper Cape are listed in Table 6 and illustrated in Figure 2. Seven distance variables were identified corresponding to seven of the sites--four propellant bag burning sites, selected to represent generally the areas where this activity took place, the center of the fire training area, the Canal Electric Company, and the aviation fuel test valve pump. While, a number of other Upper Cape sites have been identified with the potential to have contaminated the environment,[2] these seven were selected as representative of the location and nature of the contamination which has occurred in the area.

An individual's status with respect to each variable was determined by measuring the distance in miles between the site in question and the closest residence to that site that had been occupied by the individual during his period of relevant exposure (date of death minus first year of residence, or 1940 if first year of residence preceded 1940, to date of death minus the residence requirement).

The four propellant bag burning areas were considered both individually and as a group. For analyses which concerned the effect on lung cancer mortality of living near any propellant bag burning site, the single residence per subject used was that among with the shortest distance measurement to any of the four individual propellant bag burning areas.

C. Distance Variables--Leukemia

1. Distance from the MMR

Environmental analyses of the relationship between proximity of residence to the MMR and risk of death from leukemia were carried out for the subset of leukemia cases who had lived east of the Cape Cod Canal. The decision to exclude individuals who had only resided on the west side was made, because these subjects could not have been exposed at their residences to contaminated groundwater which had originated at the sites listed in Table 6. Groundwater that flows toward the Canal from the east mixes with the Canal water and does not enter the groundwater system west of the Canal.

Rather than take measurements to individual sites on the MMR, as was done for the lung cancer series, a single distance variable for the MMR sites was defined. A subject's status with respect to this variable was determined after following a set procedure: First, the

residences occupied by the subject during his period of relevant exposure were identified. Second, the distance in miles between each residence and the closest point to it on the MMR boundary was measured. Third, that residence for which this distance was the shortest was determined. And fourth, the distance between this residence and the closest point on the MMR was used as the subject's exposure value.

The reason for taking a single distance measurement relates to the direction of the groundwater flow and the location of the hazardous waste sites on the MMR. The hypothesized route of exposure for the leukemia cases was through the drinking water. The groundwater, which provides much of the drinking water on the Upper Cape, flows in all directions from a point located centrally on the MMR. With the exception of the main base landfill, the hazardous waste sites are located ear the MMR boundary. Measuring distance to the MMR boundary rather than to each individual site would, therefore, consistently include in the analysis residences generally down gradient from the sites and consistently exclude those not downgradient from the sites.

2. Distance of Residence from the Mashpee Landfill

Only those residences located to the south of the Mashpee landfill and east of the Mashpee River (Figure 4)

were eligible for analyses considering distance from the landfill as the independent variable.

These restrictions were imposed, because individuals residing in other areas could not have been exposed to groundwater contaminants emanating from the landfill. Occupants of residences situated to the north of the landfill are protected by the southward flow of groundwater from the site, and those who reside to the west of the Mashpee River escape exposure through the mixing of groundwater from the vicinity of the landfill with the river water.

If more than one of a subject's residences qualified for inclusion, the one selected was that located closest to the landfill. Each subject's exposure status was determined by measuring the distance between the landfill and the closest qualifying residence.

3. Distance of Residence from PAVE PAWS

The distribution of residences around the PAVE PAWS radar installation was also of interest. Here again, a single residence per subject, that located closest to the site was used, and a subject's value for the variable was the distance between this residence and the site. Only residences located within the azimuth of radar coverage and within five miles of the facility

were included (Figure 5) since the areas outside this coverage zone were not exposed.

D. Duration of Residence

Duration of residence on Upper Cape Cod was operationalized as the total number of years of relevant exposure (as defined in the previous section) experienced by a subject in his lifetime.

E. Distance-Duration Exposure Score

In consideration of the fact that exposure is a consequence of the combined effects of distance from sources of contamination and duration of residence near those sites, we sought to compute an exposure score that 1) included both distance and time components and 2) accounted for all residences which each eligible subject had occupied during his period of relevant exposure.

The sites from which air contaminants were known or suspected to have originated were grouped into three geographic areas (Figure 6): 1) a cluster of sites at the southeastern end of the MMR, including the fire training area and the fuel test valve dump site, designated as "the southern area"; 2) the central region of the MMR, including several of the propellant bag burning sites and the base landfill, designated as "the central area"; and, 3) "the northern

area", including the remaining propellant bag burning sites on the MMR and the Canal Electric plant.

Because of the close proximity of the sites within a grouping, distance measurements were made between each qualifying residence and the closest of the sites in a grouping (Figure 6), such that a single variable was defined for each area (as opposed to each site).

For the leukemia cases (and controls), only one distance variable was defined for this analysis. Distance measurements were made between each qualifying residence and the point on the boundary of the MMR which was closest to it, as described in Section D.1.

An individual's exposure score for a given variable was computed by the formula: $E = \sum \text{duration} \times 1/(\text{distance})^2$. That is, we summed over all qualifying residences the products of the number of years the subject had resided at a given residence and the squared inverse of the distance of the residence from the nearest exposure source in a grouping (or the closest point on the base for the leukemia series).

Underlying the use of this formula is the assumption that one's potential for exposure to chemicals released into the air or groundwater would decrease with distance of residence from the source and increase proportionately to the duration of one's residence in the five-town area. The literature

supports the hypothesis that contaminant dispersion occurs according to the inverse square law; that is, that concentrations generally decrease in relation to the squared distance from the source.[40]

VII. CONTROL VARIABLES

While many factors might be expected to act as confounders in the association between exposure to the Upper Cape environment and the risk of leukemia and/or lung cancer, not all were addressed within the context of this study. Attention to potential confounders, such as occupational exposures, was not generally within the scope of this study. This issue would be addressed in the cancer study to follow this investigation.

For lung cancer, control of sex was achieved through restriction of entry to females; partial control of age, and of sex for leukemia, was achieved through matching in the subject selection phase.

The use of multivariate methods was considered to be beyond the scope of this investigation, so, although smoking histories were collected for the majority of subjects, the small number of subjects which remained after the imposition of residence requirements generally precluded the use of stratification to control for this variable or for any residual confounding by age and sex. It should be emphasized, however, that the issue of confounding will be addressed in the planned incidence study.

VIII. DATA ANALYSIS

A. Standardized Mortality Ratios

Standardized Mortality Ratios (SMRs) were computed by applying age-sex-specific lung cancer and leukemia mortality rates for the state as a whole to the appropriate portions of the five-town population.[41]

The expected numbers of disease-specific deaths thus generated were then summed over the various age-sex strata and compared to the observed number of deaths. The SMRs were calculated for two broad time periods (1969-1978 and 1979-1985), and subjects for all five Upper Cape towns were considered as a single group.

The five-town population figures by which the state (Massachusetts, 1969-1985) rates were to be multiplied were adjusted to take into account the fact that not all members of the five-town population had lived on the Upper Cape long enough for their experience there to have contributed to lung cancer or leukemia mortality. This adjustment was accomplished as follows: 1) responding controls (both sexes combined) were stratified according to age; 2) within each age category, controls were classified according to the number of years which had elapsed between the subject's first year of residence on the Upper Cape and his/her death; classes were established differently for each cause of death;

for leukemia, classes were "less than five years", "five to nine years", "ten or more years", and "five or more years"; for lung cancer, classes were "less than ten years", "ten to nineteen years", "twenty or more years", and "ten or more years"; 3) the proportion of controls in each age category which fell into each time-since-first-year-of-residence class was computed; and, 4) the calculated proportion was applied to the appropriate age-sex-specific five-town population figure to produce an estimate of the number of five-town residents in a given age-sex category whose first year of residence on the Upper Cape dated back a particular number of years.

Since the sexes were combined for the calculation of the proportions, the figure multiplied by the number of five-town males in a given age category was the same as that applied to the number of females. Even though the sexes may have differed in their tendencies towards long-term residence, we did not have sufficient numbers of controls in each age-sex category to produce separate estimates for males and females.

The numbers of observed five-town deaths from lung cancer and leukemia within each age-sex category correctly attributable to short-term, long-term or very long-term residence classes were determined in similar fashion, using estimates derived from data collected on our case groups. Males and females were not combined for this purpose.

Finally, observed and expected numbers of deaths were summed over age-sex categories for a given time-since-first-year-of-residence stratum, such that SMRs related the observed to expected values for the various strata adjusted for whatever differences had existed during the relevant time period between the state and the five-town population in terms of age and sex.

The small numbers of individuals from our sample that were used to estimate the proportions of the diseased and non-diseased populations that fell into the various strata must be appreciated. In consideration of this problem, we calculated each SMR three times--once using the proportional estimates based on our study sample, once using the lower limits of 90% confidence intervals for those estimates, and once using the upper limits of the confidence intervals for all estimated proportions.

B. <u>Environmental Analyses</u>

Data pertaining to subjects who had died between 1969 and 1978 were analyzed separately from those pertaining to the more recent time period. Mapped residences are those which qualified according to the shortest minimum residence requirement (5+ years for leukemia, 10+ years for lung cancer), but case-control analyses relating each independent variable to risk of death from leukemia or lung cancer were

performed separately for the different groups of subjects (five towns combined) who met each of the minimal residence requirements.

The objective of the case-control analyses was to compare the estimated risk incurred by having experienced a particular level of exposure to that incurred by having experienced the lowest level of exposure. In other words, our goal was to estimate relative risks. In preparation for these analyses, discrete exposure categories were created for each independent variable considered.

For duration of residence, measured to the half-year, exposure classes for lung cancer were established as follows: lowest level of exposure = fewer than 5 years; second level = 5 to 14.5 years; third level = 15 to 19.5 years; fourth level = 20 to 24.5 years; fifth level = 25 or more years. Since the time windows established for leukemia were narrower than those established for lung cancer, no leukemia subjects had durations of residence longer than twenty years, so, for leukemia analyses, the highest level was omitted.

Categories for the distance variable were "less than or equal to 0.5 miles"; 0.6 - 1.0 miles"; 1.1 - 1.5 miles"; "1.6 - 2.0 miles"; 2.1 - 2.5 miles"; "2.6 - 3.0 miles"; "3.1 - 4.0 miles"; "4.1 - 5.0 miles"; and "greater than 5.0 miles". Case-control analyses were performed for all distance variables except for that operationalized as the distance

between the Mashpee landfill and the subject's closest qualifying residence. For all other distance variables, categories were combined, such that reported odds ratios compare the risk of leukemia or lung cancer associated with living greater than five miles from a site to that incurred by living within five miles of the site.

For the calculated exposure levels (distance/duration formula), categories were initially established as follows: lowest level of exposure (level 1) = values less than 0.09; second level of exposure (level 2) = values between 0.10 and 0.19; third level of exposure (level 3) = values between 0.20 and 0.25; fourth level of exposure (level 4) = values between 0.26 and 0.50; fifth level of exposure (level 5) = values between 0.51 and 1.00; and the highest level of exposure (level 6) = values greater than 1.0.

In order to allow recognition of dose response relationships while avoiding extremely broad confidence intervals (due to small numbers in certain categories), neighboring categories were combined when an expected value less than 5.0 was calculated for any cell in a 2x2 table comparing a higher exposure level to the lowest. Because both the number of deaths and the response rates were lower for the earlier decade vs. the more recent time period, analyses pertaining to subjects who had died between 1969 and 1978 employed fewer categories than those involving subjects who had died more recently.

Once exposure categories were established as described above, relative risks were estimated by odds ratios (Mantel-Haenszel psi)[42] and associated 95% confidence limits (Cornfield's).[43] In a few cases, when the odds ratios and confidence intervals for neighboring exposure categories were extremely close, categories were collapsed further in order to produce a more precise estimate of the relative risk.

The overall hypothesis that the distribution of subjects among exposure (or distance or duration) categories was the same for the cases and controls was evaluated by the chi-square test of homogeneity of proportions.[44]

In cases where the hypothesis of homogeneity of proportions was rejected at at least the 0.10 level, and where, even in the absence of a significant overall test, an obvious increasing or decreasing trend in the odds ratios with increasing exposure was apparent, a test for linear trend was employed.[45]

All calculations with the exception of the chi-square test of homogeneity (done by hand calculation) were performed on the HP-41CV programmable calculator, according to programming instructions written by Rothman and Boice.[42a]

Contingency table analyses of the relationships between the other exposure variables and risk of death from lung cancer and leukemia were performed similarly.

RESULTS

I. STUDY POPULATION

A. Response Rate

1. Lung Cancer

A total of 205 female lung cancer deaths between 1969 and 1985 were identified among the residents of Barnstable, Bourne, Falmouth, Mashpee, and Sandwich. Approximately 61 percent of these deaths occurred during the years 1979 through 1985.

The number of female lung cancer deaths for 1969 through 1985 was originally estimated at 209. In fact, only 205 cases were confirmed. This result does not represent under ascertainment, because the four additional cases were reported to MDPH as out-of-state deaths. Death certificates are not available for out-of-state deaths, and every name is considered confidential; therefore, these four cases could not be included in this study. In any case, it is unlikely that the small number of cases excluded as out-of-state deaths would markedly affect the study results.

Table 7 shows the distribution of lung cancer cases and controls according to the type of response obtained. Residential histories were assembled for 188, or 91.7%, of the

deaths. Of those for whom histories were not obtained, there were two refusals to participate and the remaining fifteen subjects could not be located. The 188 individuals for whom a residential history was obtained represented the case population used in the lung cancer SMR analysis.

Eleven of the histories were obtained only through review of town directories. Because use of town directories did not always provide information for all years of interest for the environmental analyses, only those subjects for whom a telephone interview was completed were included in this phase. The study population used for the environmental analyses was thus somewhat smaller than that used for the SMR calculations.

Complete histories (by informant interview) were obtained for 177 lung cancer deaths. This represents 86 percent of the starting lung cancer population. The proportion of lung cancer cases who died between 1969 and 1978 and for whom informant interviews were successfully completed was 79 percent. The figure was 91 percent for cases who died between 1979 and 1985. These 177 cases were used in the environmental analyses.

Only 201 controls were selected for the 205 cases. This discrepancy is explained by the fact that four additional cases were identified after the original selection process had been completed. Of the 201 controls selected, 173 residential

histories were obtained, or 86 percent. These 173 controls were used as part of the comparison group in the SMR analysis. Interviews were successfully completed for 157, or 78 percent, of the original controls. Informants for approximately 67 percent of the 1969-1978 control deaths and 85 percent of the 1979-85 control deaths were successfully interviewed.

2. Leukemia

Table 8 shows the distribution of leukemia cases and controls, males and females combined, according to the type of response obtained. A total of 115 male and female leukemia deaths were identified among the residents of the five study towns for the period 1969 through 1985. The actual number of leukemia deaths was 117, but two out-of state deaths had to be excluded from the study. Residential histories were obtained for 97, or 88.2 percent, of the leukemia cases. The proportion was somewhat higher for those cases who died during the more recent time period, 1979 through 1985. As with the lung cancer cases, failure to obtain a history was usually due to our inability to locate an informant. The 97 leukemia cases were used as the study population in the SMR analysis.

Complete residential histories were obtained through informant interviews for 87, or 76 percent, of the starting leukemia population. Informants for about 75 percent of the 1969-1978 leukemia deaths and 84 percent of the 1979-1985 leukemia

deaths were successfully interviewed. These 87 cases were used in the environmental analyses. A total of 110 controls were selected for the leukemia cases. The proportion for whom residential histories were obtained was only slightly less than that observed for the cases. Residential histories were obtained for 95, or 86 percent, of the controls. These 95 control subjects were used in combination with the equivalent group of lung cancer controls as the comparison population in the SMR analysis.

Informant interviews were successfully carried out for 84, or 73 percent, of the selected controls. The proportion interviewed did not differ across time periods. These 84 controls were used in the environmental analyses.

B. Time Between First Year of Residence and Death

Table 9 shows the distribution of cases and controls for the two time periods and both causes of death according to the number of years which had elapsed between each individual's first year of at least summer residence on the Upper Cape and death. Subjects included are those for whom residential histories were obtained through informant interviews. For each cause of death, subjects were distributed among three "time-since-first-year-of-residence" categories. The different categories used for the lung cancer and leukemia series reflect the different induction times assumed for each cancer type.

For the 1969-1978 lung cancer series, 78 percent of cases and 76 percent controls resided on the Upper Cape for at least three months ten years or more prior to death (sum of percentages associated with the "10-19 years" and "20+ years" categories). If a long-term resident is defined as one who lived on the Upper Cape for at least three months twenty years or more prior to death, then about 63 percent of cases and 53 percent of controls qualified as long-term residents.

For the later time period, about 67 percent of both cases and controls met the "10+ years" residence requirement, and 43 percent of cases vs. 46 percent of controls met the "20+ years" residence requirement.

For the 1969-1978 leukemia series, 71 percent of cases were classified as long-term residents when a minimum requirement of five years between first year of residence and death was employed; 79 percent of controls met this criterion.

Approximately 89 percent of the cases who died during the later time period resided on the Upper Cape for a period of at least three months five years or more prior to death, as compared to 81 percent of the controls. If long-term residence is defined as ten or more years between first year of residence and death, then 54 percent of the leukemia cases who died between 1969 and 1978 qualified vs. 62 percent of the controls. The analogous figures for the 1978-1985 leukemia case-control series were 74 percent of cases vs. 50 percent of controls.

Table 10 shows the distribution of the study population used in the SMR analysis according to the number of years between first year of residence and death. Included in this analysis were all cases and controls for whom a residential history was obtained from interviews and/or town directories. It should be noted that, for each time period, the same control group was used for both the lung cancer and leukemia cases, this control group consisting of all controls for the lung cancer and leukemia cases combined. The control groups were combined for the SMR calculations, because the distribution of controls among these categories was used to represent that of the Upper Cape population, and it was desirable to have as large a group as possible for this purpose.

For 1969 through 1978, 80 percent (Table 7) of the lung cancer cases were included in this analysis. Approximately 99 percent of the lung cancer deaths between 1979 and 1985 were included. For leukemia cases (Table 8), residential histories were obtained for 80 percent of the 1969-1978 cases and 88 percent of the 1979-1985 cases.

Comparison of Tables 9 and 10 shows that combining the two control groups made little difference with respect to the distribution of subjects among the categories "<10 years", "10-19 years", and "20+ years". The effect was more marked, however, for the categories "<5 years", "5-9 years", and "10+ years".

C. Eligibility

Tables 11 through 14 display the distribution of the individuals who were used in the environmental analyses according to the two residence requirements established for each cause of death. The residence requirements determined subject eligibility for inclusion in the case-control analyses relating death from leukemia and/or lung cancer to the following independent variables: duration of residence on the Upper Cape, distance between residence and environmental contamination source, and a third variable that included both distance and duration.

The number of individuals eligible for the "distance" analysis is not shown in the tables but is always equivalent to the number eligible for the analysis involving the distance-duration formula. Minor differences in the number of subjects eligible for the "duration" and "distance-duration" analyses can be noted. The differences are due to missing data; i.e., unknown address, for some subjects.

Table 11 shows the number of lung cancer cases and controls in the 1969-1978 series who qualified for the environmental analyses. Of the 63 cases (Table 7) for whom an informant interview was obtained, 49, or 78 percent, first resided on the Upper Cape at least ten years prior to death. These 49 cases were eligible for all three environmental analyses employing the "10+ years" residence requirement. About 64 percent, or 40 cases, were eligible when the "20+ years" residence requirement was used. Three

controls whose term of residence on the Upper Cape began ten to nineteen years prior to death and one control who met the "20+ years" residence requirement could not be included in the "distance" or "distance-duration" analyses because of missing addresses.

The proportions of lung cancer cases and controls in the 1979-1985 series who were eligible for the environmental analyses were smaller than those reported above for the earlier time period. Table 12 shows that about 68 percent of the included cases were eligible based upon the "10+ years" residence requirement and only 43 percent were eligible when the "20+ years" requirement was employed. The percentages of eligible controls were similar to the percentages of eligible cases.

The numbers of leukemia cases and controls used in the environmental analyses are shown in Tables 13 and 14. The percentage of leukemia cases who died between 1969 and 1978 that were eligible for the environmental analyses was smaller than the eligible proportion of lung cancer cases for the same time period. This was true even though the minimal residence requirement for leukemia was less stringent than that employed for the lung cancer cases and controls. About 71 percent of the leukemia cases were eligible for environmental analyses after disqualifying those whose first year of Upper Cape residence occurred within five years of death. Only 51 percent of the leukemia cases qualified when the "10+ years" residence requirement was employed. The percentage of eligible controls was

somewhat higher than the percentage of eligible cases, regardless of the residence requirement imposed. It can be seen from table 14 that more than 91 percent of the cases for the 1979-1985 leukemia series were eligible for the environmental analyses when the minimal residence requirement was employed. Approximately 76 percent were eligible when the stricter residence requirement was used. The proportions of leukemia controls eligible for inclusion under the "5+ years" and "10+ years" residence requirements were 83 percent and 52 percent respectively.

D. Age

The percentage of originally matched subjects eligible for inclusion in the environmental analyses ranged from 35 percent to 62 percent, depending upon the case-control series considered and the residence requirement employed. Because the matched pairs were disrupted through this loss of subjects, the age and sex distributions of the groups which contributed information to the case-control analyses are of interest.

Tables 15 through 18 display age-sex-specific information and allow comparisons between cases and controls for each set of analyses performed.

From Table 15, it can be seen that, when the "10+ years" residence requirement was imposed upon the 1969-1978 case-control series, cases tended to have been older than controls (55 percent of cases over 64 years old vs. 47 percent of controls), and that this

discrepancy particularly affected the 75-84-years-old category. The lung cancer cases and controls in the 1979-1985 series were more similarly distributed among age categories, but a slightly higher percentage of controls vs. cases were over 64 (63 percent vs. 59 percent) at the time of death.

Lung cancer cases and controls who met the stricter residence requirement (Table 16) showed a pattern of case-control differences for age similar to that observed for the previously discussed group.

The age- and sex- distributions of leukemia cases and controls who met the "5+ years" and "10+ years" residence requirements are shown in tables 17 and 18 respectively.

Controls in the 1969-1978 series were somewhat older than cases at the time of death; about 78 percent of cases were over 64 years old vs. 84 percent of controls. Control groups contained equal or nearly equal percentages of males and females, but males predominated among cases. Furthermore, regardless of the residence requirement employed, the percentage of cases who were male was about 20 percent higher than the corresponding value for controls.

Cases in the 1979-1985 series were slightly older than controls at the time of death, and the difference was greater when the "10+ years" residence requirement was imposed. The only exception to the rule of approximately equal percentages of males and females

occurred among controls, using the "10+ years" residence requirement. Only 33 percent of the subjects in this group were males.

E. Smoking Status

Smoking information is summarized in Tables 19 and 20. From Table 19, it can be seen that smoking rates for leukemia cases and controls ranged from 44 percent to 67 percent. Leukemia cases who died between 1969 and 1978 showed somewhat less of a tendency to smoke cigarettes than either the controls for this case series or the subjects who died in the more recent time period.

The difference in smoking habits between lung cancer cases and their controls was more consistent, showing high smoking rates of cases vs. controls. Also noteworthy is the observed similarity in smoking rates between leukemia subjects (both cases and controls) and lung cancer controls.

Table 20 displays the mean packyears (# of packs smoked per day times number of years smoked) who smoked. Of particular interest is the fact that, for both time periods, mean packyears for lung cancer cases who smoked exceeded the analogous values calculated for controls by about 15 percent. Values computed for leukemia cases and controls showed no such difference. Furthermore, for both time periods, mean packyears estimated for lung cancer cases exceeded the means calculated for leukemia cases. Interestingly, however, leukemia controls had smoked more heavily than lung

cancer controls, a finding which is probably related to the inclusion of males in the leukemia case-control series. Somewhat surprisingly, we found that subjects who died in the more recent time period had been heavier smokers than subjects who died between 1969 and 1978.

F. Occupation at Time of Death

Information pertaining to "usual occupation" was gleaned from death certificates of all subjects for whom an informant interview was completed. This information is summarized in Tables 21 and 22. For the lung cancer patients, who were all women, the most common occupation listed was homemaking, with lung cancer cases for the earlier time period having been somewhat less likely than controls for this series to stay at home. No such case-control difference was apparent in any of the other three groups.

Large case-control differences were observed in the "clerical/sales," "service," and "technical/professional " categories, but the results lacked consistency. For example, although the percentage of lung cancer cases who died between 1969 and 1978 and had been employed in the clerical or sales professions was about two times the percentage of controls, it was the controls who were more likely than the cases to have pursued this type of career in the 1979-1985 series. For the leukemia subjects, a similar reversal of the direction of the case-control difference was observed for the "technical/professional" category. For the service professions, a notable case-control

difference which was not apparent in any other comparison was observed for the 1979-1985 lung cancer series. Even for the leukemia subjects, which included men, very few of the death certificates listed "chemical industry," "manufacturing," or "agriculture" as the usual occupation.

G. Causes of Death for Controls

Significant conditions listed on control death certificates appear in Table 23, along with the numbers and percentages of subjects in the various control groups diagnosed with each illness. As expected, cancer and heart diseases were involved in the deaths of a large proportion of the subjects in each comparison series.

The proportion of lung cancer controls that had been diagnosed with cancer exceeded 40 percent. A breakdown of control cancers by site is presented in Table 24, from which it is evident that the number of individuals who had suffered from any particular type of cancer was generally quite small. A notable exception to this rule occurred among controls for the 1979-1985 lung cancer series, in which group, breast, colorectal, and female reproductive cancers had affected 18 percent, 7 percent, and 9 percent of subjects respectively. Across the board, these three cancers, along with pancreatic, were those listed most frequently on control death certificates.

The proportion of 1969-1985 leukemia controls who had died of cancer ranged from 21 to 27 percent (Table 24). Of these 23

cancer controls, three had suffered from cancers that have been associated with chemical exposure in other epidemiologic studies. These three subjects died of liver, brain, and bladder cancer. Again, breast, colorectal, and female reproductive organ cancers represented the greatest proportion of control cancers.

II. ANALYTIC RESULTS

A. <u>Standardized Mortality Ratios</u>

The SMRs for lung cancer and leukemia stratified by decade of death and by the number of years between the first year of residence on Upper Cape Cod and death are displayed in Tables 25 and 26 respectively.

It is clear from the figures for 1969 through 1978 that lung cancer rates were significantly elevated for long-term residents regardless of how a long-term resident was defined ("10+ years" or "20+ years" residence requirement). In the SMR calculations, the proportion of the Upper Cape population that met each residence requirement was estimated by 1) the proportion of controls that qualified, 2) the upper limit of the 90 percent confidence interval for the proportion of controls that qualified, and 3) the lower limit of the 90 percent confidence interval for the proportion of controls that qualified. The proportions of lung cancer and leukemia deaths attributable to long- and short-term segments of the population were estimated similarly from data collected on the case groups. All three methods of calculating the SMRs produced values indicative of statistically significant elevations in Upper Cape lung cancer death rates for long-term residents.

For leukemia just the reverse seems to have been true. Age-sex-adjusted leukemia rates were not elevated for the period 1969-1978 among long-term Upper Cape residents--the excess cancers having been confined to the portion of the population consisting of people whose first year of residence had occurred only a few years prior to death. The picture is somewhat less clear for the more recent time period, but the SMRs were consistently elevated for long-term residents. Once again, regardless of how long-term residence was defined ("5+ years" or "10+ years" residence requirement) or which estimates of the long-term proportions of the population and the case group are used. However, whether differences between the Upper Cape and the rest of the state were statistically significant did seem to depend on the definition of long-term residence--statistical significance having been achieved for both lung cancer and leukemia only when "long-term" was defined as first year of residence having occurred 10 or more years prior to death.

B. Environmental Analyses

1. General Mapping Results

Appendix III is a compilation of maps showing each eligible Upper Cape residence. Each town is represented by three maps; one for the residences of 1969-1978 lung cancer cases and controls, one for the 1979-1985 lung cancer cases and controls, and one for the residences of the 1969-1985 leukemia cases and controls. These maps serve as graphical representations of the tables discussed above.

In interpreting the maps, it should be kept in mind that the maps depict all residences, not individual cases and controls. As a consequence, multiple residences for subjects are included on the maps. It should also be noted that groupings of residences, besides possibly representing multiple residences, represent groupings in space but not necessarily in time. The residences shown could occur as early as 1940 or as late as 1980. Therefore, two residences shown on a map to be adjacent to each other, may actually have occurred many years apart, thereby greatly reducing the significance of the grouping. The purpose of showing all residences is to illustrate the location of the residences with regard to the MMR and other environmental sites of interest.

Though five residences in the area of the airport were noted for 1979-85 lung cancer cases, these five residences represent four cases. There was no grouping of residences of leukemia cases near the airport. Groupings of leukemia residences that were observed in Barnstable and Mashpee occurred over a wide time period (1969-85). The residences were not observed to be groups in time as well as space, which would be more suggestive of a true cluster.

Examining the maps in Appendix III along with Figures 8a - 8c provides another perspective on the distribution of residences. Figures 8a - 8c illustrate the approximate 1970 population density in the five Upper Cape towns. The distribution of lung cancer and leukemia cases on the maps can be seen to follow the

population distribution in the towns. That is, groups of cancer residences appear to be located in densely populated areas.

2. Distance to Suspected Air Pollution Sites - Lung Cancer

Tables 27 through 44 summarize the results of our investigation of the relationship between lung cancer mortality and proximity of residence to suspected sites of air contamination on the Upper Cape. Comparisons shown in the latter set of tables involve only two distance categories, because there were too few cases to allow finer stratification of the data.

a. Canal Electric Plant

Examination of Table 27 shows that the vast majority of lung cancer cases never resided within five miles of the Canal Electric plant, regardless of which residence requirement was employed or which time period was considered. Approximately 92 percent of the 1969-1978 series never resided within five miles of the plant. Of three lung cancer cases who had lived within five miles of the plant, only one had resided within two miles of the plant.

For the later time period and the "20+ years" residence requirement, the proportion of lung cancer cases who had lived less than five miles from the plant was slightly higher than that observed for the earlier time period. Employing the "10+ years" residence requirement, 87 percent of the cases never

lived closer to the plant than five miles. Ten cases (13 percent) had lived within five miles of the plant, three within one mile. Employing the stricter residence requirement, one of four cases (8 percent) who had lived within five miles of the plant, had lived within one mile. Control residences were distributed similarly to case residences for both time periods.

Table 28 summarizes results of contingency table analyses of the relationship between lung cancer mortality and proximity of residence to the Canal Electric plant. Results for both time periods and both residence requirements were consistent in that the risk of lung cancer mortality associated with living within five miles of the plant was below 1.0 for each analysis.

b. Propellant Bag Burning Areas

Tables 29 through 38 illustrate the distribution of cases and controls according to the distance between propellant bag burning sites (Figure 2) and the subject's closest residence to each site.

Table 29 shows that at least 80 percent of the cases who died before 1979 never lived within five miles of the northeast propellant bag burning site. Only one case had lived within two miles of the site.

For those deaths which occurred between 1979 and 1985, about 77 percent of both cases and controls never lived closer to the site than five miles. Two cases who qualified under the "10+ years" residence requirement had lived between one-half and one mile from the site.

Control residences were distributed similarly to case residences, as indicated by the data presented in Table 30. Odds ratios were close to 1.0, except when the "10+ years" residence requirement was employed for 1969-1978 series. The odds ratio estimating the risk for this group incurred by living within five miles of the site was 1.92, implying that living within five miles of the site incurred almost twice the risk of death from lung cancer as living farther away. However, six out of the eight cases who had resided within five miles of the site never lived closer to it than four miles.

Table 31 shows the distribution of cases and controls according to the distance between the northwest propellant bag burning area and the subject's closest residence to the site.

For the 1969-1978 lung cancer case-control series, 75 percent of the cases who met the "20+ years" residence requirement never lived within five miles of this site. None of the cases had ever lived closer to the site than 2.6 miles.

When the "10+ years" residence requirement was employed, cases who died during the later time period were found to have lived closer to the site than cases who died before 1979. None of the cases, however, had lived within 1.5 miles of the site. The distribution of control residences was similar to that of case residences.

Table 32 shows that odds ratios were close to 1.0 for each case-control analysis relating lung cancer mortality to residence near the northwest propellant bag burning area.

The distribution of cases according to the distance between a propellant bag burning area located in the western part of the MMR and the subject's closest residence to the site are shown in Table 33. Cases who died in the earlier time period had generally lived closer to the site than controls. Still, none of the cases had ever resided closer to the site than 1.6 miles. None of the cases who died in the later time period had lived closer to the site than 2.1 miles.

Table 34 shows the contingency table analysis for these data. Odds ratios calculated for the 1969-1978 series were 2.05 ("10+ years" residence requirement) and 3.48 ("20+ years" residence requirement).

The fourth propellant bag burning area considered was located in the east-central part of the MMR. This site is called "the southern propellant bag burning area" in this report.

Distribution of lung cancer cases and controls according to the distance between this site and the subject's closest residence to the site are shown in Table 35. The vast majority of cases and controls never resided within five miles of this site. Nearly 90 percent of subjects who died before 1979 never lived within ten miles of the site. When the "10+ years" residence requirement was imposed, six cases were found to have lived between 2.6 and 5.0 miles from this site. Similar results were observed for controls and for subjects who died during the later time period. None of the cases who met the "20+ years" residence requirement had lived closer to the site than 2.6 miles.

Table 36, showing contingency table analyses relating lung cancer mortality to distance of residence from the southern propellant bag burning area, displays an odds ratio of 1.54 for the 1969-1978 case-control series ("10+ years" residence requirement). The odds ratios for the other comparisons were either at or below 1.0. In fact, when the "20+ years" residence requirement was imposed, the upper limit of the confidence interval estimate of the odds ratio calculated for the 1979-1985 series was below 1.0. The implication is that the risk of lung cancer mortality incurred by living within five miles of the southern propellant bag burning site was than that associated with living farther away.

Tables 37 and 38 display results of analyses relating lung cancer mortality to residence near any of the four propellant bag burning areas. As with the other case-control analyses considering distance between a residence and a site as the independent variable, a single residence per subject was used. To identify the appropriate residence for this analysis, the distance between each residence and the closest propellant bag burning site was measured. The residence with the shortest distance was used.

Table 37 shows the distribution of cases and controls according to the distance between the selected residence and the closest propellant bag burning site. For those individuals who died between 1969 and 1978, none of the cases who met the "10+ years" residence requirement had lived closer than 1.6 miles to any of the propellant bag burning sites.

About 74 percent of cases never lived within five miles of a site. Seventy percent of the cases who met the "20+ years" residence requirement never lived within five miles of a site. Results were similar for those subjects who died between 1979 and 1985 and met the "20+ years" residence requirement, but two cases who were living on the Upper Cape ten years prior to death had lived within one mile of a site. Table 38 displays the results of contingency table analyses relating risk of death from lung cancer to proximity to a propellant bag burning area. Two notable results were found.

The odds ratio for subjects in the 1969-1978 case-control series who met the "20+ years" residence requirement was 1.80, implying that those who lived within five miles of a propellant bag burning site incurred almost twice the risk associated with living more than five miles away. For the more recent time period, both of the odds ratios were below 1.0.

Table 39 shows the distribution of cases and controls according to the distance between the Fuel Test Valve Dump and the subject's closest residence to the dump. None of the cases who died before 1979 had lived within five miles of this site. Almost 90 percent of cases who died in the later time period never resided within five miles of this site, and 100 percent never resided closer to this site than 2.6 miles.

The contingency table analysis displayed in Table 40 shows that the risk of lung cancer mortality was somewhat higher for those who had resided within five miles of the site vs. those who had not.

c. Fire Training Areas

The last site of interest in the "distance" analyses was the fire training area on the MMR. Although three fire training areas existed on the MMR, distance was measured to a point central to the three closely located areas.

Table 41 shows the distribution of cases and controls according to the distance between this site and the subject's closest residence to the site. Of the deaths which occurred during the period 1969 through 1978, only four cases who met the "10+ years" residence requirement had resided within five miles of this site. The distance between the site and the closest case residence was three to four miles. Control residences for the earlier time period were distributed similarly to case residences.

For the later time period, close to ninety percent of the cases never resided within five miles of the site. Eight cases who met the "10+ years" residence requirement had resided with five miles of the site. Of these eight cases, six had resided between four and five miles from the site, one had lived between 2.6 and 3.0 miles away, and one had lived between 1.6 and 2.0 miles away.

Table 42 summarizes the contingency table analyses relating lung cancer mortality to proximity of residence to the fire training area. The fact that all of the odds ratios reported in this table are below 1.0, implies that the risk of death from lung cancer was somewhat lower for those who had lived within five miles of the area vs. those who had not.

3. Distance to Suspected Groundwater Contamination Sites - Leukemia

a. Massachusetts Military Reservation

Distance measurements for analyses concerning the relationship between leukemia mortality and proximity of residence to sources of water contamination on the MMR were taken as follows: The distance between each eligible residence and the closest point to it on the boundary of the MMR was measured. The residence with the shortest measurement was used in the analysis. The appropriateness of this approach, vs. one accounting for distance to individual sites, derives from the topography of the base. Since groundwater generally flows in all directions emanating from a point near the center of the base, distances measured to the MMR boundary were essentially along the lines of the groundwater flow and excluded residences not downgradient from the sites. These analyses excluded case and control residences located west of the Cape Cod Canal, because occupants of these residences could not have been exposed to groundwater east of the Canal.

Table 43 shows the distribution of cases and controls according to the distance between the MMR boundary and the subject's closest residence to the boundary. About 79 percent of cases who died before 1979 never resided within five miles of the MMR boundary, as compared to only 60 percent of controls. The closest case residence was located between 1.1 and 1.5 miles from the boundary. Only two cases had resided

within three miles of the MMR. Three controls from this earlier time period had lived within one-half mile of the MMR. Results of contingency table analyses for this time period (Table 44) suggest that the risk of dying of leukemia for those who lived within five miles of the MMR was lower than that associated with living more than five miles away.

The number cases in the 1979 through 1985 series who had resided close to the MMR exceeded that for both the control group for this time period and the cases from the earlier time period (Table 43). About 43 percent had resided within five miles of the MMR, and three cases had resided between 0.6 and 1.0 mile from the boundary. In contrast, only about 36 percent of controls had lived within five miles of the MMR. The contingency table analyses displayed Table 44 show that the odds ratios were somewhat elevated.

b. Mashpee Landfill

Groundwater in the vicinity of the Mashpee landfill flows in a southerly direction toward the Mashpee River.[15] Only residences located in the general direction of the groundwater flow would be potentially exposed to groundwater contaminants. When the residential data in the area south of the landfill was examined, it was observed that only two leukemia cases who had died during 1969-1978 had resided

within five miles of the landfill. Four leukemia deaths from 1979-1985 lived within five miles of the site, when the stricter residence requirement was employed. However, all of the cases (and controls) lived on the opposite side of the Mashpee River from the landfill. Since the groundwater from the landfill area would be expected to mix with the river, none of the residences on the opposite side of the river would have the potential for exposure to the groundwater. Therefore, there is no evidence that any leukemia cases ever resided within the area of known or potential groundwater contamination in the area of the Mashpee landfill (refer to Appendix III).

4. Other "Distance" Analyses - Leukemia

In addition to the analysis of distance to specific environmental sites, the distribution of residences for the leukemia subjects was also examined in relation to the Canal Electric plant, the PAVE PAWS installation, and identified groundwater plume areas.

Because only a few subjects had lived within five miles of these sites, the data were not tabulated, nor were case-control analyses pursued. Results are summarized below.

a. Canal Electric Plant

Five leukemia cases and one control who died before 1979 had resided within 3.0 miles of Canal Electric. No other subjects in this series had resided within five miles of the plant.

Four cases and one control who died between 1979 and 1985 had resided within 1.5 miles of the plant. These five subjects were the only ones in this series to have resided within five miles of the plant.

b. PAVE PAWS Site

Four leukemia cases in the 1969-1978 series had resided within 5 miles of the PAVE PAWS facility and the azimuth of radar coverage (Figure 5), but none of these cases were alive in 1978, when the installation first went into operation.

Of leukemia cases who died during the later time period, four had resided within the azimuth of coverage or area of potential exposure. One of these cases died in 1979, about one year after PAVE PAWS went into operation. Of the remaining three cases, one had resided between 1.5 and 2 miles from PAVE PAWS and two had resided between 2 and 3 miles from the facility. Only one control had resided in the area after 1978, about two miles from the site.

c. Groundwater Plume Areas

Figure 7 illustrates the approximate locations of known plumes affecting private wells on the Upper Cape. No leukemia cases had ever resided within any of the areas of groundwater contamination. These areas include the plumes originating

near the southern boundary of the MMR and in the vicinity of the Mashpee landfill.

5. Duration of Residence - Lung Cancer

Duration of residence was considered as an independent variable separate from location in the analyses which generated the data displayed in Tables 45 through 50.

Tables 45 and 46 summarize data pertaining to duration of residence in excess of the two residence requirements imposed for each cause of death. Statistics displayed include the mean, standard deviation, median, and range. What is apparent from Table 45 is that, for lung cancer cases and their controls, there is little variability across time periods or between case and control groups; mean duration in excess of the "10+ years" residence requirement averaged about fifteen years, and mean duration in excess of the "20+ years" residence requirement averaged about ten years. The only noteworthy case-control difference concerns the median, which was somewhat higher for cases in the 1969-1978 series than it was for controls.

Statistics pertaining to duration of residence in excess of the "10+ years" residence requirement for leukemia cases and their controls (Table 46) were necessarily different from analogous figures calculated for the lung cancer subjects, due to the longer maximum empirical induction time allowed for lung cancer (i.e. for leukemia, we did not count any years of residence that

had occurred more than 25 years prior to death). Furthermore, mean and median durations were slightly longer for the early time period vs. the later one, perhaps indicating a greater tendency for in-migration in more recent years. Case-control differences were quite small, however, with controls tending to have resided slightly longer on the Upper Cape than cases for the earlier decade, the reverse trend having been observed for the later time period.

The case-control differences obtained using the less strict residence requirement mirrored those discussed immediately above (Table 46); two facts should be noted, however: 1) the magnitude of the differences in the means was greater when the "5+ years" residence requirement was imposed; and 2) the medians showed case-control differences as well.

Results of contingency table analyses relating duration of residence on Upper Cape Cod to risk of death from lung cancer for subjects who met the "10+ years" residence requirement (Table 47) reveal somewhat of a trend of increasing risk with increasing duration for the 1969-1978 case-control series. Nevertheless, the odds ratio which compares the risk for those who resided on the Upper Cape for twenty or more years to that associated with residence in the five towns for less than five years is considerably lower than that comparing the effects of fifteen to twenty years of residence to less than five years. This means that the moderately long-term residents had more than four times the risk of dying of lung cancer than did the very short-term residents,

but individuals who lived longer on the Upper Cape had less than two times the risk.

In contrast to estimates pertinent to the earlier time period, odds ratios calculated for the 1979-1985 case-control series employing the shorter induction time assumption were closer to 1.0 (Table 47).

Imposition of the stricter residence requirement (Table 48) made little difference for the 1979-1985 series, but departures from the null value were much less marked for the odds ratios calculated for the earlier time period using the longer induction time assumption vs. the "10+ years" residence requirement.

6. Duration of Residence - Leukemia

For leukemia, contingency table analyses of data obtained for the earlier time period and the shorter induction time assumption (Table 49) generated consistently low odds ratios. For the 1979-1985 case-control series, odds ratios comparing risk of death from leukemia for individuals who lived on the Upper Cape for any of three durations longer than five years, was about three times that experienced by very short-term residents.

When the stricter residence requirement was imposed (Table 50), the odds ratios computed to compare the leukemia risk of those who resided on the Upper Cape for five to nine years or for ten or more years to that incurred by shorter-term residents who had

died in the earlier decade were less than 1.0.

Values calculated for the later time period varied with the residence requirement imposed. Here, the large case-control differences found with the "5+ years" residence requirement disappeared when the stricter requirement was imposed.

To summarize, there is some evidence in the data exhibited here of a positive effect of duration of residence on risk of death from lung cancer. This effect was apparent, however, mainly for the earlier time period under the assumption of a ten-year minimum empirical induction time. With respect to leukemia, the greatest effect was observed when a five-year minimum empirical induction time was assumed, but the effect was either positive or negative, depending upon the time period in question.

7. Exposure Score - Lung Cancer

Before considering results presented in this section, please refer to Tables 11 and 12 which display the numbers of individuals used in the various case-control analyses concerning lung cancer.

Results of the contingency table analyses pertaining to the relationship between residence near the three geographic groupings of air pollution sites on Upper Cape Cod and risk of death from lung cancer are displayed in Tables 51 - 56.

Odds ratios which estimate the risk of dying from lung cancer incurred by experiencing a given level of exposure, as determined by the exposure formula, vs. that incurred at the lowest exposure level are displayed with their associated 95% confidence intervals. The results of an overall chi-square test of homogeneity which evaluates the hypothesis that cases and controls were distributed similarly among exposure categories is reported at the bottom of each table. Some tables also display the results of a chi-square test of linear trend, but this test was only performed when either 1) the hypothesis of homogeneity of proportions was rejected at at least the 0.10 level or 2) in the absence of a significant chi-square test, the odds ratios suggested a trend of increasing or decreasing risk with increasing exposure.

Tables 51 and 52 summarize the results (for both time periods) of our investigation of the impact of residence near the southern air pollution sites. Excluded from the groups of cases and controls reported on in Table 51 were subjects whose first year of residence on the Upper Cape occurred within 10 years of their deaths. The stricter residence requirement (first year of residence occurring no more recently than 20 years prior to death) was imposed on entry into the analyses shown in Table 52.

The data displayed in Table 51 suggest a trend of decreasing risk with increasing exposure to the southern sites for subjects who died before 1979 and met the "10+ years" residence requirement.

The trend described immediately above was notably absent when the later time period was considered. All of the odds ratios, in fact, were close to 1.0.

Imposition of the more stringent residence requirement (Table 52) revealed similar patterns for the 1969-1978 case-control series. For the more recent time period, the highest odds ratio, occurring as it had in the previous table in the 0.25-0.49 exposure range, this time exceeded 2.0.

To summarize the results gleaned from consideration of the southern grouping of sites as the independent variable, although odds ratios were consistently elevated for the 1979-1985 case-control series, no evidence emerged to implicate the activities in this area as a cause of lung cancer deaths for the 1969-1978 series; in fact, increasing exposure was associated with decreasing risk for this time period.

The next two tables (Tables 53 & 54) display results of analyses identical to those described above, but the point from which measurements were taken for the distance component of the exposure variable was the nearest of the central air pollution sites.

For both time periods, employing a ten-year empirical induction time assumption (Table 53) resulted in a fluctuating pattern of high and low odds ratios relating exposure to the central sites to risk of death from lung cancer. It is noteworthy, however,

that odds ratios for three of the four comparisons made for the later time period were below 1.0.

Application of the stricter residence requirement (Table 54) resulted in odds ratios below 1.0 for the earlier decade. For the more recent time period, the estimates were once again mainly close to the null value--this time favoring the positive side.

Comparison of the results of the analyses treating the central grouping of sites as the independent variable to those considering the southern grouping of sites as the exposure source reveals a single notable difference involving the 1969-1978 case-control series. When the minimal residence requirement was imposed, the decreasing trend in the odds ratios which was evident in all of the analyses relating to this time period for the southern area was not apparent for the central area.

This discrepancy, however, no longer existed after imposition of the twenty-year residence restriction. In general, exposure to the central area was not associated with increased lung cancer morality.

Tables 55 and 56 display results of contingency table analyses relating risk of death from lung cancer to residence near the northern sites. The previously noted trend of decreasing risk with increasing exposure failed to emerge in these analyses. The odds ratios calculated for the 1969-1978 time period suggest that the risk associated with the highest category of exposure exceeds

that incurred by very low exposure.

For the more recent time period, no excess risk was observed when the minimal residence requirement was employed. Imposition of the stricter residence requirement produced a pattern of odds ratios quite similar to that shown in Table 52 for the southern area, with high risk (O.R. = 2.10) associated with moderately high exposure. In all other analyses involving the 1979-1985 case-control series and exposure to the northern sites, odds ratios were close to 1.0.

8. Exposure Score - Leukemia

Before considering the results reported on in this section, please refer to Tables 13 and 14 which display the numbers of individuals used in the various case-control analyses concerning leukemia.

Results of contingency table analyses pertaining to the relationship between residence on the Upper Cape and risk of death from leukemia are exhibited in Tables 57 and 58.

For the 1969-1978 case-control series, regardless of how exposure was defined or what residence requirement was imposed, odds ratios tended to be less than 1.0; furthermore, employing the "5+ years" residence requirement produced an odds ratio which indicated that the risk of dying from leukemia associated with very high exposure to the base was less than that associated with

the lowest level of exposure. Furthermore, results of the chi-square test for linear trend indicate a decrease in risk with increasing exposure.

For the more recent time period, all of the odds ratios exceeded 1.0 when the five-year residence requirement was employed, and that comparing the risk at the highest level of exposure to that associated with the lowest was nearly 2.7 (Table 57).

The assumption of a ten-year induction time for leukemia (Table 58) revealed the same general pattern (decreasing risk with increasing exposure) for the earlier time period as the five-year residence requirement had. For the later time period, a clear pattern of increasing risk with increasing exposure failed to emerge.

DISCUSSION

The results of this investigation of lung cancer and leukemia mortality and Upper Cape residence are difficult to interpret due to the assumptions made regarding the determination of exposure status and the inherent uncertainty and imprecision in the results. Nevertheless, the different methodological approaches taken in this investigation permitted evaluation of the residential data from different perspectives. The various analyses provided generally consistent results regarding the relationship between exposure to specific areas of environmental contamination on the Upper Cape, as estimated by time and location of residence, and lung cancer and leukemia mortality. In the discussion which follows, findings are interpreted in light of the limitations of the study.

I. STANDARDIZED MORTALITY RATIOS

The results of the Standardized Mortality Ratio (SMR) analyses indicate that Upper Cape lung cancer mortality was significantly in excess for both time periods (1969-1978 and 1979-1985) among the long-term residents. Leukemia mortality was significantly in excess among the long-term residents for the 1979-1985 deaths and among the short-term residents for the 1969-1978 deaths.

The validity of these results rests on the soundness of the methods employed to adjust the numbers of observed and expected deaths from lung cancer and leukemia such that they reflect only the long-term residents of the Upper Cape.

In evaluating the methodology, the following factors must be considered: The SMRs were based on age-specific estimates of the proportion of long-term residents in the Upper Cape population. Because of the small sample size, the statistical stability of the estimates, and of the resultant SMRs, may be decreased. As a result, the SMRs may be imprecise estimates of observed versus expected mortality among long-term residents. Furthermore, if the control sampling frame was biased, even with high response rates, the estimates may be inaccurate.

Since our sample was selected randomly from a list of all individuals who died as permanent Upper Cape residents during the time period of interest, the question of representativeness rests upon the degree to which this group resembles the Upper Cape population as it existed between 1969 and 1985. If the long-term portion of the general population was underestimated, the expected values used to calculate the SMRs would also be underestimated and the resultant SMRs would be inflated. If the long-term portion of the population was overestimated, then the SMRs would be artificially low.

Several factors might lead to overestimation of the proportion of long-term residents. One such factor is socioeconomic status (SES). Long-term residents may be of lower SES than in-migrants and low SES groups tend to have higher death rates.

Even if our adjusted SMRs are underestimates of the true values, however, correcting sources of error which have may have tended to depress them artificially would not alter our conclusion that SMRs for lung cancer and leukemia are significantly elevated for long-term Upper Cape residents.

If, on the other hand, our sample was biased towards short-term residents, then our conclusions may be incorrect. It is certainly conceivable for the selection of controls from death files to have resulted in inflated SMRs. For example, if there was a tendency for illness to have been a motivating force behind in-migration, then we may have underestimated the proportion of long-term residents in the general population and overestimated the degree of difference between observed and expected numbers of deaths.

II. ENVIRONMENTAL ANALYSES

A. Interpretation of Findings - General Considerations

Results of epidemiologic studies must be weighed against such considerations as capacity of the study design to reveal associations and generate unbiased estimates of effects, the reasonableness of the hypothesized association from a theoretical standpoint, and the consistency of results with those of other investigations of the same or similar phenomena.

1. Plausibility of the Hypothesized Associations

The possibility of carcinogenic effects from exposures to suspected or identified air and groundwater contaminants on the Upper Cape is supported by results of experimental animal studies and occupational and environmental epidemiologic studies.[30,31,60-66]

Animal studies provide the strongest evidence for the carcinogenic potential of TCE and PCE, probable human carcinogens, though the evidence is still limited.[28,67] Mice orally exposed to TCE developed liver and lung cancer,[68] Furthermore, inhalation of TCE by mice has caused lymphomas[69] in one experimental study and lung tumors, and leukemia,[70] in another. In the latter investigation, however, it was impossible to separate the effects of TCE from benzene, another carcinogen which was present as a contaminant.

PCE has induced liver cancer in mice,[28] and a National Toxicology Program Report on PCE has demonstrated that PCE may be associated with leukemia in rats.[71]

It should be noted that it is not known how a chemical identified as a carcinogen in animals will act in humans. If a chemical causes a particular type of cancer in animals, it should not be assumed that it will necessarily cause the same type of cancer in humans, if it is a human carcinogen at all.

Most of what is known regarding cancer risks in humans from exposures to TCE and PCE or related solvents has been derived from occupational studies. In general, results from studies of occupational exposure to TCE and PCE have not been consistent, and it is often difficult to attribute excess cancer risk to TCE and PCE exposure, because the workers are frequently exposed to benzene and other carcinogens along with TCE and/or PCE.

Excess mortality from cancers of the bladder[62] and skin[63] has been observed among workers exposed to TCE and PCE in the dry cleaning industry, and mortality from leukemia was elevated in one 1968 study of occupational exposure to these chemicals.[63] Other studies have yielded different results, but kidney cancer has emerged as the most commonly elevated malignancy.[72-74]

In Woburn, Massachusetts, researchers from the Harvard School of Public Health carried out a survey to determine if contaminated municipal wells may have been associated with elevated rates of childhood leukemia in the community. The principal contaminants in the wells were TCE and PCE. An association was found between the pattern of distribution of the contaminated drinking water within the town and the incidence of childhood leukemia. This analysis, while controversial, suggests a possible relationship between TCE and PCE exposures and leukemia.[29]

A recently completed study in New Jersey also found that a relationship may exist between leukemia incidence and VOC contamination of drinking water, at least among females. The VOC contaminants included TCE (up to 46 ppb) and PCE (up to 16 ppb).[75]

The relationship between exposure to fuel and leukemia has been suggested by occupational studies of service station workers and automobile mechanics.[76-78] Gasoline and solvents containing benzene were regarded as potential etiologic agents. There is no evidence to link benzene with lung cancer.[28]

Hydrazine is a chemical used as a component of fuel at certain locations on the MMR. Orally administered hydrazine has been shown to induce lung and liver cancer in rats,[28] and ingestion of hydrazine derivatives has caused tumors of the colon in this species.[66] Nasal tumors have been induced in both rats and hamsters following inhalation.[79] A study of hydrazine workers failed to show any unusual excess of cancer.[80] 2,4-Dinitrotoluene, a constituent of the chemical mixtures used to propel artillery and mortar shells, is a probable human carcinogen. Though it has induced liver tumors in rats, there currently is no evidence of carcinogenicity in humans.[23,24,81]

Soot and benza[a]pyrene are examples of air pollutants that may be carcinogenic in humans. Benza[a]pyrene, in

particular, is important because it occurs ubiquitously in products of incomplete combustion. It also occurs in fossil fuels, crude oils, used motor oil, and gasoline.[84] The carcinogenic effect of soot may actually be due to the presence of compounds such as benza[a]pyrene.[28]

Holland, et al.,[82] has conducted a comprehensive review of the evidence for health effects of particulate air pollution and concluded that there is no scientifically acceptable evidence from recent mortality studies or long-term exposure to air pollutants that can implicate a particular level at which an increase in death can be identified. This conclusion is supported by other researchers.[83] However, studies of populations downwind from chemical plants have identified excess cancer.

There is no strong evidence indicating that exposure to radio frequency electromagnetic field radiation (RFR), the type of radiation emitted from the PAVE PAWS radar installation, increases the risk of cancer in humans or experimental animals.[85] In fact, it is not known how RFR, at the frequencies transmitted at PAVE PAWS, might induce cancer or other health effects. The results of the 1986 community exposure survey indicate that RFR was detectable only at sites in the direct path of transmission of radiation from PAVE PAWS, and that the levels measured were far below health and safety guidelines. Furthermore, considering that the facility first went into operation in

1978, the maximum number of years of exposure to RFR by the study subjects would only have been seven years. Thus, the duration of exposure may have been insufficient to induce cancer in the study population.

2. Appropriateness of Exposure Assessment

In the environmental analyses described here, location and duration of Upper Cape residence were used as surrogate measures of exposure to air and groundwater contaminants. Consequently, of major importance in interpreting the data is an assessment of the suitability of these measures as indicators of exposure status. If our method of establishing exposure status was inadequate, then the failure to identify clusters of residences around contamination sites or large odds ratios cannot be accepted as evidence against a causal relationship between environmental contamination and mortality from leukemia and lung cancer.

The significance of lung cancer subjects' residing a specific distance from a site is not clear, since the geographic area of potential exposure from air contaminants is not known. In general, though, the individuals exposed to the highest concentrations of air pollutants will generally be those located downwind of and nearest to the source.[53] It is important to keep in mind, however, that exposure to both air and groundwater contaminants may not

occur concurrently with the contaminating activities. In the case of air pollutants, volatilization of chemicals and distribution of dusts may take place over an extended period of time. The situation is similar for water pollutants; whether or not the occupants of a particular residence are exposed to chemicals released nearby depends upon physical forces which govern their absorption into groundwater and migration away from the site of entry. Furthermore, residents may use municipal water unaffected by the groundwater contamination or they may use bottled water. Even those individuals with private wells living in areas of groundwater contamination may not be exposed to the pollutants; private wells usually are shallow, and the groundwater contamination may be located deeper in the aquifer such that the contaminants are not drawn into the well.

In this investigation, it was assumed that all subjects were potentially exposed to groundwater at their residences. Since most individuals living on the Upper Cape have access to groundwater through municipal wells, an association between location of residence and leukemia mortality may not have been an unreasonable expectation.

If any subjects were exposed to carcinogens through either air or water, the possibility that subjects were misclassified cannot be discounted.

3. Temporal Relationship

For an exposure to have induced a cancer, the exposure must have preceded the diagnosis of the disease by a number of years at least equaling the induction time of the cancer. In this investigation, we assumed that the minimum induction time for lung cancer was ten years, and for leukemia, five years.

Our estimates of the time between exposure and death from lung cancer and leukemia were used to define those residences which were potentially related to the observed cancers. If the estimates used were far from the true values, individuals and residences would have been misclassified as to eligibility status, and our maps would provide a false impression of the distribution of eligible subjects' residences around sites of interest. Moreover, estimates of effect derived from case-control analyses would be lower than the true values in the population.

There are no firm data on the true induction periods for lung cancer and leukemia. Estimates from the recent literature range from as short as one or two years for leukemia induced by ionizing radiation to over fifty years for lung cancer induced by asbestos.[37] With the exception of radiation-induced cancer, an induction period of at least five years is required to give credence to a hypothesis suggesting a cause and effect relationship between exposure

to environmental contaminants and cancer.[37,48,49] Furthermore, it must be assumed that more time should be allowed in a mortality study to account for the time between diagnosis and death. Of relevance here is the fact that approximately 89 percent of lung cancer cases and 72 percent of leukemia cases are deceased within 5 years of diagnosis, according to 1979 statistics.[50]

In the absence of specific knowledge regarding the duration of the induction periods for lung cancer and leukemia, an attempt was made to avoid misclassifying individuals with regard to the relevant time period of potential causal action. This was accomplished by establishing a time window of exposure based upon each of two assumptions of induction time for each type of cancer[51].

B. Mapped Residences

The review of maps upon which the qualifying residences of the long-term Upper Cape cancer subjects were plotted reveals no clear pattern suggesting an association between of cancer mortality and exposure to the MMR sites or to the other Upper Cape sites considered.

The strongest evidence against an association with leukemia is that no leukemia cases had ever resided in any of the areas where the groundwater is known to be contaminated.

The mapping results do indicate that residences for some leukemia subjects were located downgradient from certain environmental sites; in particular, the propellant bag burning sites located in the northern and western part of the MMR, the fire training areas, the sewage treatment plant, and the fuel test valve dump site. However, the rate of groundwater flow is such that, assuming that groundwater plumes from these sites actually exist, exposure to contaminated groundwater may have occurred only recently. Consequently, there is reason to hypothesize that the cancers observed in these areas could not have been caused by contamination originating from the nearby sources, because insufficient time had elapsed between exposure and death from cancer.

The distribution of residences near the Canal Electric Plant and the Hyannis Airport and other areas of concern, including some golf courses, cranberry bogs, and hazardous waste sites identified by the DEQE, was not suggestive of a relationship between residence near those sites and cancer mortality. No clustering of residences was noted, and, very few leukemia cases had ever resided near the sites examined.

The question of a relationship between the risk of leukemia mortality and contamination of parts of the Falmouth and Sandwich municipal water supplies with trihalomethanes and PCE respectively could not be addressed in this study; however, it is worthy of note that no leukemia cases had resided in any of the areas where high levels of PCE have been measured.

C. Distance to Suspected Sources of Environmental Contamination

These findings are perhaps the most useful, because they provide information relative to the potential for exposure as a result of location of residence.

As noted in a previous section, it is difficult to evaluate the significance of living a particular distance from a source of contamination. In interpreting the data on distance of case residences from sources, though, it is useful to keep the following in mind: Although the combined effects of high summer temperatures, which facilitate volatilization of chemicals, and breezy conditions might seem capable of effecting high concentrations of certain contaminants at locations relatively far from their sources, these same meteorological conditions also lead to contaminant dilution.[54] Thus, if most cancer victims are found to have resided relatively far from sources, it is reasonable to conclude that exposure did not occur at the residences of these subjects to an extent sufficient to have caused their cancers. The unknown quantity is whether two miles or five miles is too far for contaminants to have migrated at significant levels.

D. Case-Control Analyses

1. Interpretation - General Considerations

It is important to recognize that the matched case-control design of this study was instituted in the interest of 1) estimating as accurately as possible the SMRs as they apply to the long-term residents of the Upper Cape and 2) evaluating the distribution of case residences in a relatively unbiased manner.

For several reasons, the data are not well suited to statistical inference; nevertheless, categorical data analyses were conducted and the odds ratios, associated confidence intervals, and test statistics reported, mainly in the interest of fully exploring the available data and to supplement findings of the planned incidence study. That is, in the event that small effects are undetectable in the incidence study, consistency with values reported here would lend credence to both sets of study results. The data should be interpreted cautiously because of the following limitations:

<u>Sample Size</u>: Because of the small sample size, estimates of the strength of associations are imprecise, as indicated by the width of the 95% confidence intervals. Each confidence interval consists of two values x and y, and any value between x and y is a possible result of this study as a

consequence of sampling error. The following is a more precise interpretation: If a 95% confidence interval is bounded by the values x and y, then if the same study were done the same way 100 times, 95 of those studies (samples) would yield estimates between the values x and y. It should be clear from this explanation that even with narrow confidence intervals, many other factors must be considered before accepting an odds ratio as the true value which applies to the population.

Another ramification of using a small sample is that differences between cases and controls must be quite large in order to be detected as statistically significant. Therefore, one must exercise caution in interpreting the confidence intervals with reference to statistical hypothesis testing.

<u>Potential for Misclassification of Subjects:</u> The likelihood that subjects were misclassified as to exposure status and eligibility was discussed in previous sections. Misclassification probably has occurred to some extent, and the effect of this source of error on case-control analyses is to make odds ratios lower than the true values in the population. This should not be taken to mean that our odds ratios are probably underestimates of the true values. This would only necessarily be the case if random misclassification were the only source of error. In this study systematic biases may also have affected the odds

ratio, and such sources of error may have caused odds ratios to either underestimate or overestimate the true values.

Confounding: Confounding is a type of systematic bias which may have distorted the measures of association. Confounders are factors related to both the exposure variable and the cause of death. When confounders are not controlled by the design or analytic methods, the odds ratio may be an underestimate or an overestimate of the true value.[46] Examples of confounders for the relationship between environmental exposure and both leukemia and lung cancer are socioeconomic status, age, sex, and occupational exposures. Smoking might confound the relationship between the environment and lung cancer.

The age-sex-matched design of the study helped to control the confounding effects of these two variables. Unfortunately, it was not feasible to match cases who had been long-term Upper Cape residents to controls who also met minimum residence requirements. Thus, the cases and controls whose residences were mapped and whose histories were considered in the case-control analyses were not strictly matched with respect to age, or even sex for leukemia cases and controls. Consideration of Tables 15 through 18 reveals that matching was not particularly effective for leukemia cases and controls or for lung cancer cases and controls who died during the earlier time period.

Regarding occupation, it is possible that exposure to chemicals in the workplace that may be causally related to the development of lung cancer and/or leukemia may also be correlated residential history. The only data collected on occupation was the usual occupation of the subject as recorded on the death certificate. Most lung cancer cases and their controls worked in what might be considered white-collar professions. Also pertinent is the fact that none of the lung cancer cases or controls listed their usual occupation in the chemical, manufacturing, construction, or agricultural industries. Similar results were noted for the leukemia cases, suggesting that occupational exposures might not appear to be serious confounders. However, the use of death certificate data as an indicator of lifetime occupational exposures is notably inadequate.

Another potential confounder for the lung cancer analyses was cigarette smoking. The proportion of lung cancer cases that smoked was 76 percent for the 1969-1978 cases and 88 percent for the 1979-1985 cases. This proportion of smokers was approximately 25 percent higher than that observed in the control group. It is highly likely that cigarette smoking played a major role in the induction of the lung cancer and should be examined more closely in future studies on the Upper Cape.

Matching also introduces confounding, which, if the matching factors are actually related to exposure, tends to bias

measures of association towards the null (that is, towards an incorrect conclusion of no relationship between exposure and disease). Although this bias, if it does in fact exist, can be eliminated through the use of analytic techniques developed for matched data, circumstances dictated that we employ unmatched analyses. More specifically, because the imposition of residence requirements occurred after controls were matched to cases, the number of pairs in which both members were eligible to be included was small - the actual number depending on the case-control series and the residence requirement imposed (see Tables 59 & 60). Predictably, the imposition of the strictest requirement disrupted the greatest number of pairs.

Furthermore, in a matched analysis the only pairs evaluated are those where the matched case and control differ with respect to the factor under study (e.g., one exposed, the other not exposed). The other pairs are ignored in the analysis. As a result, the number of pairs from which conclusions would have been drawn in this investigation, if a matched analysis had been used, would likely have been considerably less than the number of eligible pairs shown in Tables 59 and 60.

Also pertinent to the decision not to employ matched analytic techniques was the importance of establishing multiple exposure categories for the purpose of identifying linear trends. The appearance of such trends is a valuable

indicator of effect when sample sizes are small and effects are likely to be also. Matched analyses involving polychotomously scaled variables are usually only considered feasible with multivariate methods.

In evaluating the potential effects of employing unmatched analyses with these data, the following points deserve emphasis: 1) the age and sex distributions of case and control groups compared in the case-control analyses were not particularly close (see Tables 15 through 18), except for the 1979-1985 lung cancer series, for analyses in which the independent variable had no temporal component (i.e., distance analyses), 2) there is no a priori reason to expect that age and sex should be confounders. In other words, there is no particular reason to expect that age or sex would be related to the proximity of one's residence to a source of environmental pollution, 3) the confounding introduced by matching can be eliminated through stratified analyses,[46] and the results of crude stratified analyses did not suggest that conclusions should be altered, 4) often taking explicit account of the matched pairs does not seriously alter the estimate of relative risk, and this is sometimes true even when conditions of "poolability" are violated,[86] and 5) if matching is performed only on age and sex then a stratified analysis, rather than one which retains individual matching may be more appropriate.[86]

Control Sampling Frame: In this investigation, the control group was drawn from all causes of death. Between 38 and 44 percent of the lung cancer controls had died of some form of cancer. These represent 74 out of 173 controls. However, only 5 lung cancer controls had died with a type of cancer that has been associated with exposure to air contaminants (cancer of the larynx (2), bladder (2), and mouth). Most of the control cancers were breast, colorectal, or female reproductive organ cancers. These cancers are generally associated with dietary or hormonal factors and their inclusion would not be expected to bias the study results.

The proportion of leukemia controls who had died of cancer ranged from 21 to 27 percent. Of these 23 cancer controls, only 3 died from cancers that could theoretically be associated with chemical exposures. The three cancers were bladder, brain, and liver cancer. Again, breast, colorectal, and female reproductive organ cancers represented the greatest proportion of control cancers.

Though the number of environmentally associated control cancers is relatively small, their presence, as well as the presence of 7 lung cancer controls who died from pulmonary disease, may have biased the risk estimates toward the null or no difference between cases and controls.[47] It has not been established if these control subjects were classified as long-term residents or excluded from the analyses due to ineligibility based on time of residence.

Number of Hypotheses Tested: Since there were at least 125 significance tests carried out, it is anticipated that several results might appear statistically significant simply by chance..

2. Distance to Suspected Environmental Sites

No relative risk estimates were significantly above 1.0; however, somewhat elevated risk ratios were observed for the residences near the propellant bag burning sites of lung cancer cases who had died between 1969 and 1978. For the 1979-1985 lung cancer cases, risk ratios were actually lower than 1.0 for residences near the propellant bag burning sites and near the fire training areas. In both time periods, few lung cancer cases had ever resided within two miles of any of the sites investigated.

The risk of leukemia mortality from residence near the MMR was found to be somewhat elevated for those subjects who died between 1979 and 1985. This result mostly reflects the proximity of cases off the western and northern boundaries of the MMR. Only three leukemia cases (1969-1985 deaths) had ever resided within three miles of the MMR south or east of the base. Two of these had resided south and one east of the MMR. Seven cases (on the Cape side of the Canal) resided west or north of the MMR.

This is an important observation in that the only contaminated groundwater known to affect private and municipal water supplies is located in areas south of the MMR. Furthermore, the longest plume of contaminants there extends about two miles south of the base. In fact, no leukemia cases had ever resided within any of the areas where drinking water was potentially affected by groundwater known to be contaminated. This includes the area around the Mashpee Landfill. If contaminated groundwater is not potentially the cause of the leukemias, the only other environmental contaminants known are air contaminants, but there is no evidence that the contaminants from Canal Electric or from the burning of propellant bags can induce leukemia.

3. Duration of Residence

Duration of residence on the Upper Cape, as a surrogate measure of environmental exposure, provided most of the statistically significant odds ratios detected through the case-control analyses. The findings suggested that the longer the 1969-78 lung cancer subjects and 1979-85 leukemia subjects lived on the Upper Cape (for the minimum residence requirement only), the greater the risk of death.

As far we could determine from very crude age-stratified analyses, this relationship apparently was not confounded by age.

4. Exposure Score

Our air and groundwater exposure estimates, derived from the duration and proximity of a subject's residence, were based on simple assumptions of air and groundwater contaminant dispersion. This approach was taken, because it was not within the scope of this investigation to predict the movement of contaminants in groundwater or to utilize computer models to predict the behavior of chemicals released into the atmosphere. Less-than-perfect indices of exposure based upon similar assumptions have been utilized in a number of epidemiologic studies.[55-58] However, the use of residential indices of exposures without incorporating meteorological or other environmental data might presumably introduce non-differential misclassification of the actual level of exposure. As a result, risk estimates based on the exposure score may be biased toward the null or no difference between cases and controls.

This may be one explanation for the generally low relative risk estimates. Though a number of non-significant risk estimates were found to be elevated, there was no evidence of a dose-response relationship. In fact, the elevated risk estimates were usually associated only with isolated exposure scores, rather than increasing as exposure increased or remaining evenly elevated across all levels of exposure. In addition, only one statistically significant

risk estimate was found in this set of analyses. However, this finding may be due to the small sample size.

Another explanation for these results may be that the exposure scores are strongly influenced by duration of residence. The exposure formula gave more weight to duration of residence than proximity of residence. As a result, subjects with who resided for a long time in the more established coastal communities could be assigned higher exposure scores that those residing closer to the environmental sites for a shorter period of time. To further illustrate this point, among the 29 1979-1985 lung cancer cases who met the minimum resident requirement of 10+ years and resided at least an additional 20 years on the Upper Cape, only one case had ever lived within five miles of the MMR. The high exposure scores for these individuals may thus reflect long-term residence in the older residential areas rather than higher exposure to environmental contaminants.

III. SUMMARY

A. SMR Analyses

There is little evidence from this investigation to suggest that the excess mortality from lung cancer and leukemia observed between 1969 and 1985 was due in in-migration of a high-risk element. The possibility does exist, however, that the SMRs adjusted for length of residence actually overestimate the degree of elevation for the long-term residents.

B. Environmental Analyses

Different approaches to the assessment of exposure were employed to minimize the limitations of any single approach, and to allow a look at the data from different perspectives.

The evidence that few lung cancer subjects had ever resided within two miles of any of the major point sources of air pollution on the Upper Cape further suggests that the potential for exposure to the air contaminants, and subsequent risk of lung cancer, would not appear substantial. However, additional work is needed to fully delineate the potential for exposure among the cancer cases.

The strongest evidence for an association between the environmental exposures assessed and risk of cancer mortality was that duration of residence on the Upper Cape, independent of

location of residence, was associated with risk of lung cancer mortality (1969-1978 deaths) and leukemia mortality (1979-1985 deaths). In particular, as duration of Upper Cape residence increased for the 1979-85 leukemia subjects, the risk of cancer mortality also increased.

If the environment is a major factor in explaining the excess cancer mortality, why then was it not observed in this investigation? The possible underestimation of risk resulting from misclassification of exposure status, the small size of the study population, the nature of the control group, and the relative lack of attention to confounding are all reasonable explanations for the lack of statistically significant findings. Another possibility is that there are as yet unidentified areas of contamination on the Upper Cape.

With respect to the already identified sites, however, the data pertaining to location of residences are informative, because it is clear that, in order for deaths from lung cancer and leukemia to have been caused by exposure at the residence to air and groundwater contaminants released from identified sources, these contaminants must have migrated at significant levels from their sources to the residences of the cases. Thus, based on our findings, air contaminants capable of causing cancer would need to have been carried at significant levels by the wind from two to five miles in order to reach the residences of the lung cancer cases. Groundwater contaminants would need to have existed in areas as yet unidentified as contaminated, since no

leukemia cases appeared to have resided within any of the areas of known groundwater contamination.

If the induction time assumptions employed were accurate enough to allow the production of valid residence maps, the following conclusions are warranted:

1. For lung cancer deaths to have been caused between 1969 and 1978 by contamination occurring at the test valve dump site, contaminants would have to have been carried by winds at significant levels at least five miles.

2. For lung cancer deaths to have been caused between 1969 and 1978 by contamination occurring at the fire training area, contaminants would have to have been carried by winds at significant levels at least five miles.

3. For lung cancer deaths to have been caused between 1969 and 1978 by contamination occurring at any propellant bag burning site, contaminants would have to have been carried by winds at significant levels at least 1.5 miles.

4. For lung cancer deaths to have been caused between 1979 and 1985 by contamination occurring at the test valve dump site, contaminants would have to have been carried by winds at significant levels at least 2.5 miles.

5. For more than one lung cancer death to have been caused between 1979 and 1985 by contamination occurring at the fire training area, contaminants would have to have been carried by winds at significant levels at least two miles.

6. For more than two lung cancer deaths to have been caused between 1979 and 1985 by contamination occurring at any propellant bag burning site, contaminants would have to have been carried by winds at significant levels at least one mile.

7. For more than three lung cancer deaths between 1969 and 1978 to have been caused by contamination originating at the Canal Electric Plant, contaminants would have to have been carried by winds at significant levels at least five miles. For the three cases who had resided within five miles of the plant to have been caused by contamination originating at the Canal Electric Plant, contaminants would have to have migrated in a path different from the direction of the prevailing winds.

8. For more than two leukemia deaths between 1969 and 1978 to have been caused by contamination originating on the MMR, contaminants would have to have migrated at significant concentrations at least three miles.

9. For any leukemia deaths to have been caused by contamination originating from the Mashpee Landfill, contaminants would

need to have migrated at significant levels at least two miles beyond the boundaries of the identified plumes and in a direction different from that of the groundwater flow.

10. For more than four leukemia deaths between 1969 and 1978 deaths to have been caused by RFR emissions from PAVE PAWS radar installation, radiation would have to have existed at significant levels outside of not only the defined arc of radar coverage of PAVE PAWS but also outside of the towns (Bourne, Mashpee, and Sandwich).

Why would cancer be high for the Upper Cape and not for other areas, such as the Lower Cape, if the cause wasn't the environment? Most cancers will show more than a random variation in cancer rates because there are real regional variations in risk factors. Furthermore, differences can be subtle and yet be significant. For example, ethnic background can vary in a population and influence an individual's lifestyle (e.g., diet) or result in a different genetic potential for cancer. The reason for choosing to live in a certain area might relate to an individual's outlook toward healthy living. Geographic variations in social class also can reflect variations in risk factors. The risk of lung cancer, for example, increases with decreasing social class. As another example, per capita income for the Lower Cape is higher than that for the Upper Cape and so may suggest a different distribution of risk factors in those two areas, which may in turn account for the difference in the lung cancer rates.

CONCLUSIONS/RECOMMENDATIONS

This investigation was not designed to provide a definitive answer to the question of whether environmental pollution which has occurred on Upper Cape Cod over the years has contributed to the occurrence of leukemia and lung cancer in this area. Such an objective would have been unreasonable considering well-recognized limitations in terms of study size, sampling frame, definition of exposure, and attention to potentially confounding factors. The data are nonetheless valuable to the extent that they provide information relative to the potential for exposure to environmental contaminants among the lung cancer and leukemia cases on the Upper Cape. Clearly, further work is needed to quantify the risk to the population from environmental and non-environmental exposures.

Summarized below are the conclusions of this investigation.

I. FEMALE LUNG CANCER

A. SMR Analysis

The data do not indicate that in-migration was responsible for the excess mortality. Previously reported cancer mortality data seem to reflect the experience of long-term residents.

B. Environmental Analyses

1. Massachusetts Military Reservation

There is some evidence of a relationship between duration of residence on the Upper Cape and risk of lung cancer; however, this result is very weak and applies mainly to the 1969-1978 deaths and only if one assumes the minimal residence requirement. For the 1969-78 deaths, no cases had ever resided within five miles of the test valve dump, no cases lived closer than 3 miles to the fire training area, and no cases lived closer than 1.5 miles to any propellant bag burning area. For the 1979-85 deaths, no cases resided closer than 2.5 miles to the test valve dump site; only 1 case lived within 2 miles of the fire training area, and only 2 cases lived within 1 mile of any propellant bag burning area. It is not known whether contaminants from these sites were carried at significant levels by the wind for the distances necessary

to reach the residences of cases.

Because of limitations of the case-control analyses, results from these analyses are difficult to interpret. Limitations in study design which may have effected the results summarized below are discussed elsewhere. While, it would not be appropriate to base the conclusions of this investigation on the results of the case-control analyses, there was no evidence to suggest that the risk of death from lung cancer increased as exposure to the MMR sites increased. Few cases had ever resided closer than 2 miles from the sites of suspected air contamination. Though cases who died between 1969 and 1978 appeared to have lived closer than controls to some propellant bag burning areas, the opposite was observed for those residents who died between 1979 and 1985. Cases also appeared to have resided closer to the fuel test valve dump site than controls; however, the number of cases living within five miles was less than 10. Controls appeared to have lived closer than cases to the fire-training areas.

2. Canal Electric Plant

In general, results did not suggest increased risk of lung cancer among those who lived near the plant. Only three 1969-78 lung cancer deaths resided within five miles of the plant. Among the 1979-85 deaths, ten had resided within five miles of the plant. These cases had not generally resided in the direction of the prevailing winds. The area of highest

concentration of pollutants was determined to be offshore, about two miles from the plant.

II. MALE AND FEMALE LEUKEMIA

A. SMR Analysis

The data indicate that in-migration significantly contributed to the previously reported elevations in the SMRs for the 1969-1978 period. Mortality from leukemia for Upper Cape residents who died prior to 1979 was found to have been elevated only for short-term residents. For the 1979-1985 period, however, elevated mortality ratios were observed among the long-term residents, suggesting that, for this time period, in-migration did not significantly affect the cancer mortality ratios.

B. Environmental Analyses

1. Massachusetts Military Reservation

For those leukemia deaths which occurred between 1969 and 1978, there was little evidence suggesting that individuals living longer on the Upper Cape or closer to areas of known or suspected groundwater contamination were at increased risk of death form leukemia. Among these cases, only 2 had ever resided within 3 miles of the MMR. For those individuals who died of leukemia between 1979 and 1985, there existed some evidence that risk of leukemia mortality increased as duration

of residence increased. This was true only when the minimal residence requirement was employed There was no evidence suggesting increased risk with increased exposure. Though the results of the case-control comparisons are difficult to interpret in light of the limitations of the study design, mapping results indicate that no cases had ever resided within any of the areas of known groundwater contamination. For cancers to have been caused by exposure at the residence to contaminated groundwater in the area of the MMR, contaminants capable of causing cancer would likely need to have been carried by the groundwater at significant levels at least one mile and more likely three miles from the boundary of the MMR in areas not yet identified as contaminated in order to reach residences of leukemia cases.

2. Mashpee Landfill

No cases had ever resided within the area of groundwater contamination, and no cases ever resided closer than three miles to the landfill in the general direction of groundwater flow. The groundwater plumes have been identified as presently extending less than one mile from the landfill.

3. PAVE PAWS

Levels of electromagnetic radiation in the area near the installation were far below state safety levels. Levels measured in the surrounding communities were generally not

detectable. Furthermore, only four 1969-78 cases had ever resided within the azimuth of radar coverage of the facility or area of potential exposure in the towns of Bourne, Mashpee, and Sandwich. However, none of these cases was alive when the facility first went into operation. Among the 1979-85 cases, four had resided within the azimuth of exposures. The number of cases was too small to evaluate risk.

4. Other Sites

The distribution of residences near the Canal Electric plant, the Hyannis Airport, and other areas of concern, including some golf courses, cranberry bogs, and hazardous waste sites identified by the DEQE, was not suggestive of a relationship between residences near those sites and the risk of cancer. No clustering of residences was noted, and, in most situations, no leukemia cases had ever resided near the sites examined. The relationship between the risk of leukemia mortality and contamination of parts of the Falmouth municipal water supply with trihalomethanes and contamination of parts of the Sandwich municipal water supply with PCE could not be established in this study. Nevertheless, leukemia cases had not resided in any of the areas where PCE was detected at high levels.

III. RECOMMENDATIONS

The determination that long-term Upper Cape residents may have experienced higher than expected lung cancer and leukemia mortality warrants additional study.

Exposure characterization remains a critical weakness in all studies, including the present investigation. Further research that attempts to apply more sophisticated methods in the estimation of environmental exposure is required. Specifically, the area of impact of air contaminants needs to be defined, usage of public and private water supplies needs to be characterized, and geostatistical methods should be applied to fully utilize the existing environmental data and minimize the potential for misclassifying individuals with regard to their exposure status. Also needed are data concerning factors such as occupational exposures, medical history, and smoking. Such information may help in quantifying the relative contribution of environmental and non-environmental factors to the cancer experience of Upper Cape residents.

To help achieve this goal,

1) The Massachusetts Department of Public Health, in cooperation with the Massachusetts Department of Environmental Quality Engineering, will award a two-year contract of $500,000 in the spring of 1988 to a qualified research team. The purpose of this award is to conduct a detailed epidemiologic study of cancer

incidence on the Upper Cape. Seven types of cancer will be studied in this investigation termed "Phase II". The study will attempt to collect environmental, occupational, and other information through interviews of all cancer cases diagnosed between 1982 and 1985.

2) The Massachusetts Department of Public Health will continue to review the on-going environmental monitoring and update the results of the Phase I investigation, if necessary.

3) The Massachusetts Department of Public Health will continue to work with the local Boards of Health and the Barnstable County Health Department and provide assistance in the assessment of environmental and health data as it becomes available.

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F I G U R E S

FIGURE 1:
Map of the Upper-Cape

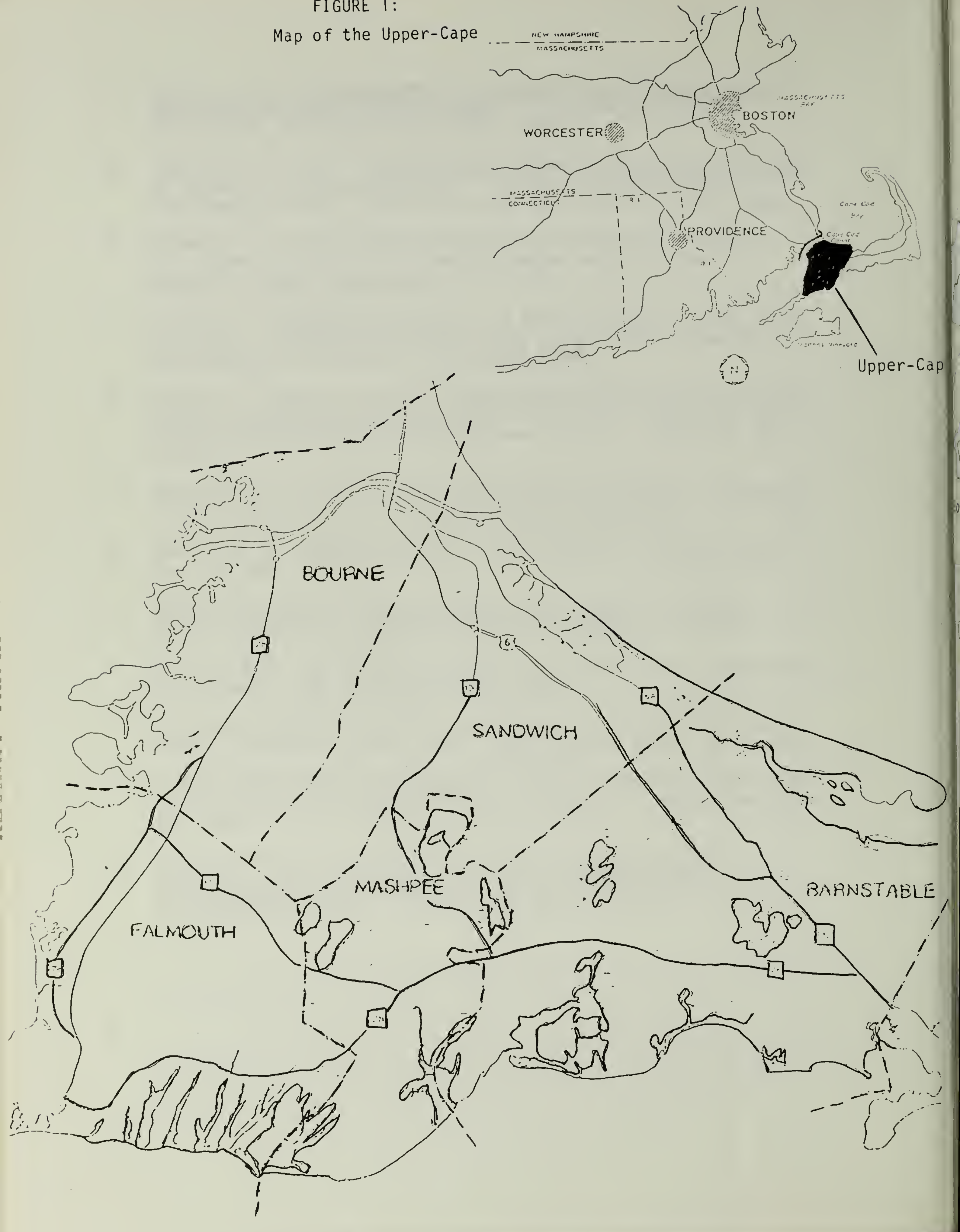
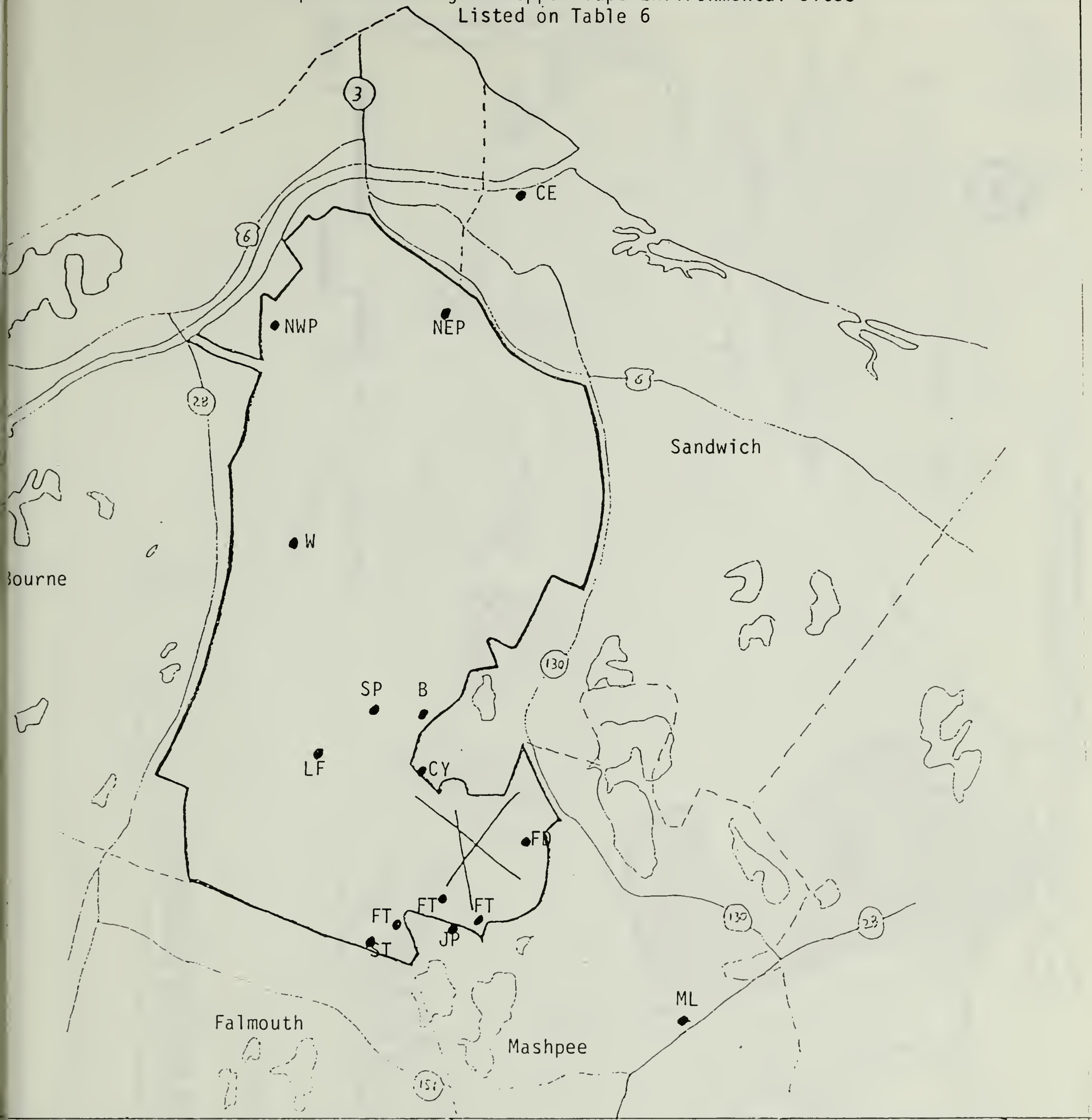


FIGURE 2:
Map Illustrating the Upper-Cape Environmental Sites
Listed on Table 6



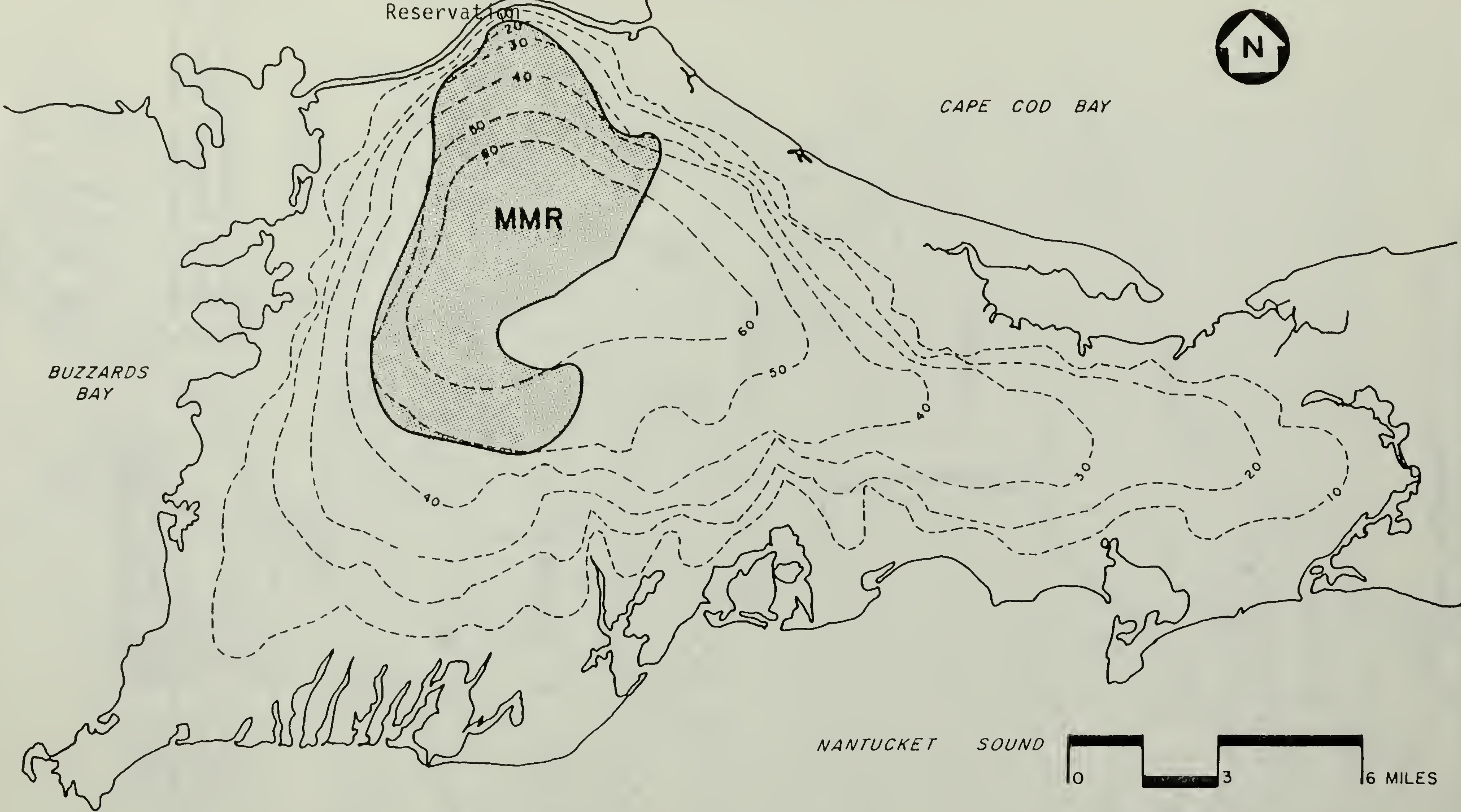
BOMARC Site
Canal Electric Plant
Contractor's Yard
Fuel Dump Valve Site
Fire Training Areas

JP-John's Pond Dump
LF-Base Landfill
ML-Mashpee Landfill
NEP-N.E. Propellant Burning Area
NWP-N.W. Propellant Burning Area

SP-South Propellant Burning Area
ST-Sewage Treatment Plant
W -West Propellant Burning Area

FIGURE 3:

Map Illustrating the Direction of Groundwater Flow in the Vicinity of the Massachusetts Military Reservation



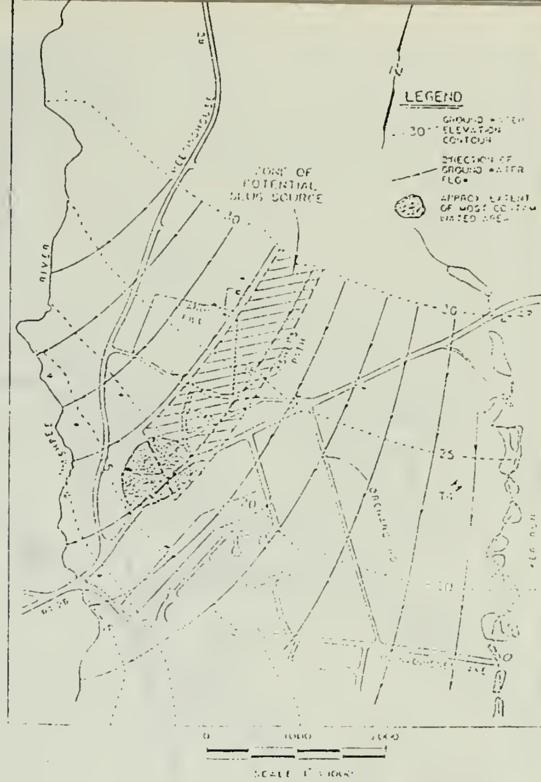
LEGEND

--10-- OBSERVED AVERAGE WATER TABLE CONTOUR, IN FT DATUM IS SEA LEVEL, CONTOUR INTERVAL 10 FT.

Source: E.C. Jordan Inc.[2]

FIGURE 4:

Map Illustrating the Location of the Mashpee Landfill



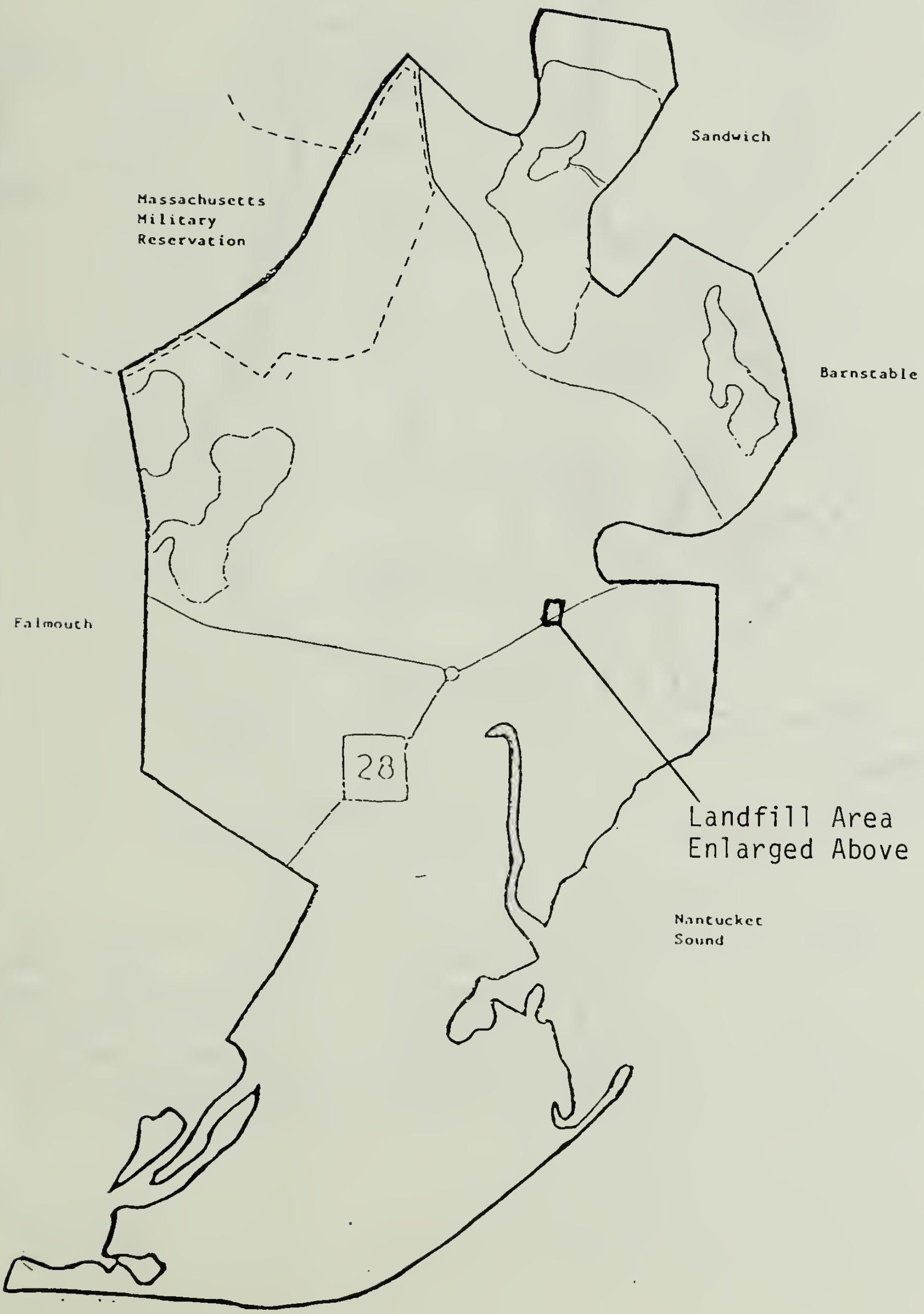


FIGURE 5:

Map Illustrating the Azimuth of Radar Coverage of the PAVE PAWS Facility

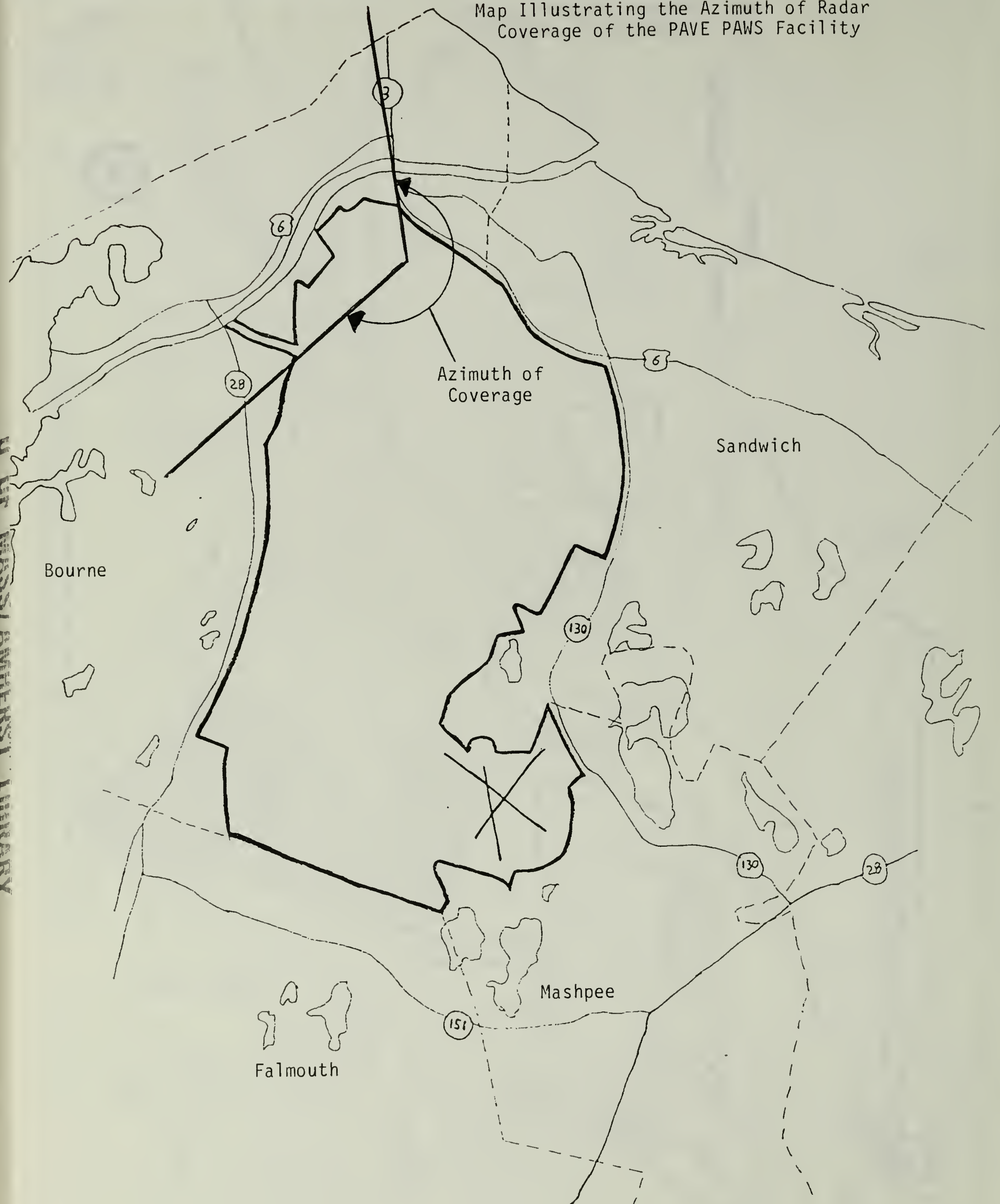
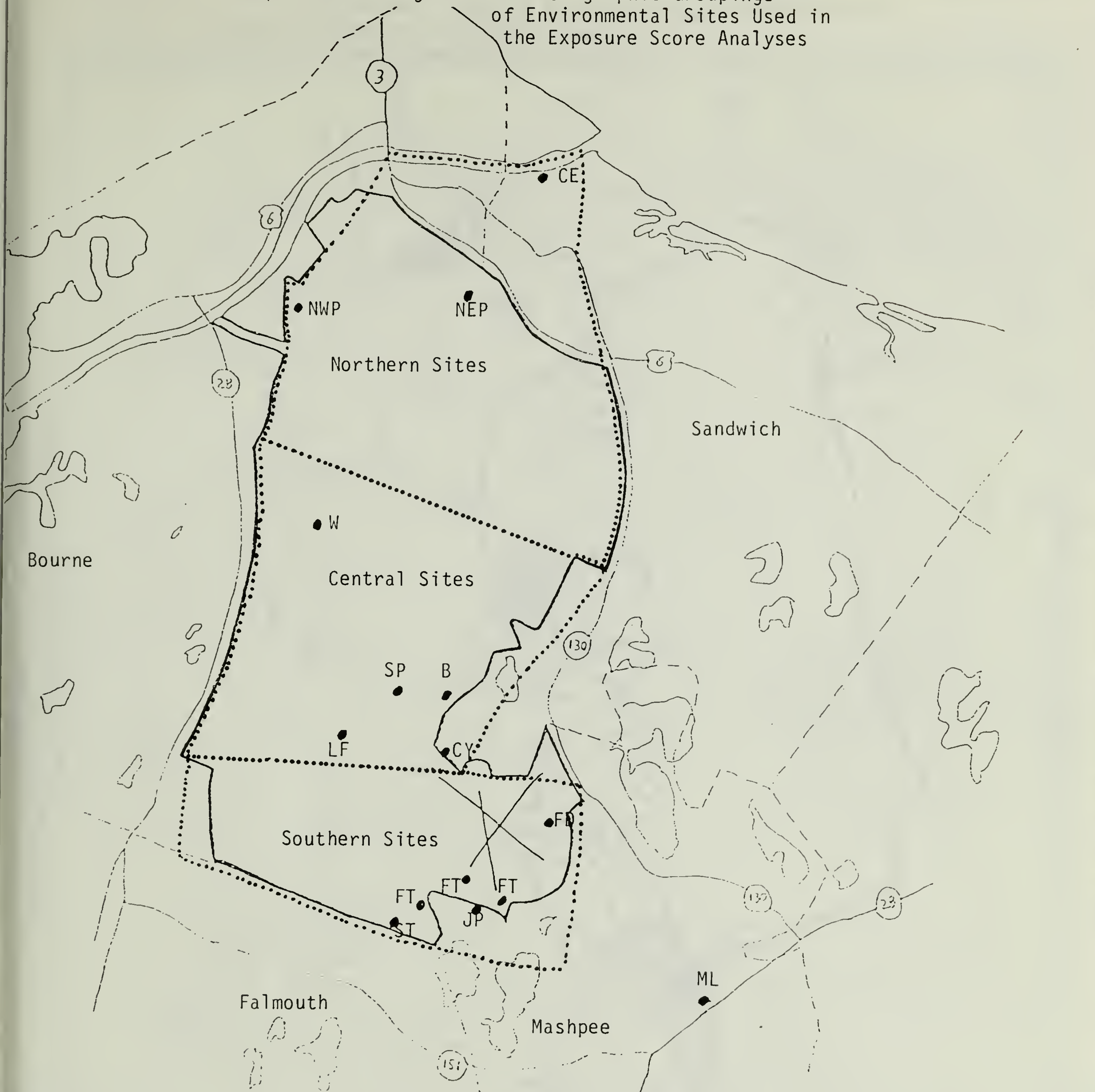


FIGURE 6:
Map Illustrating the Three Geographic Groupings of Environmental Sites Used in the Exposure Score Analyses



B-BOMARC Site
CE-Canal Electric Plant
CY-Contractor's Yard
FD-Fuel Dump Valve Site
FT-Fire Training Areas
JP-John's Pond Dump
LF-Base Landfill
ML-Mashpee Landfill
NEP-N.E. Propellant Burning Area
NWP-N.W. Propellant Burning Area
SP-South Propellant Burning Area
ST-Sewage Treatment Plant
W -West Propellant Burning Area

FIGURE 7:

Map Illustrating the Location of Known Groundwater Plumes Potentially Affecting Private Wells on the Upper-Cape

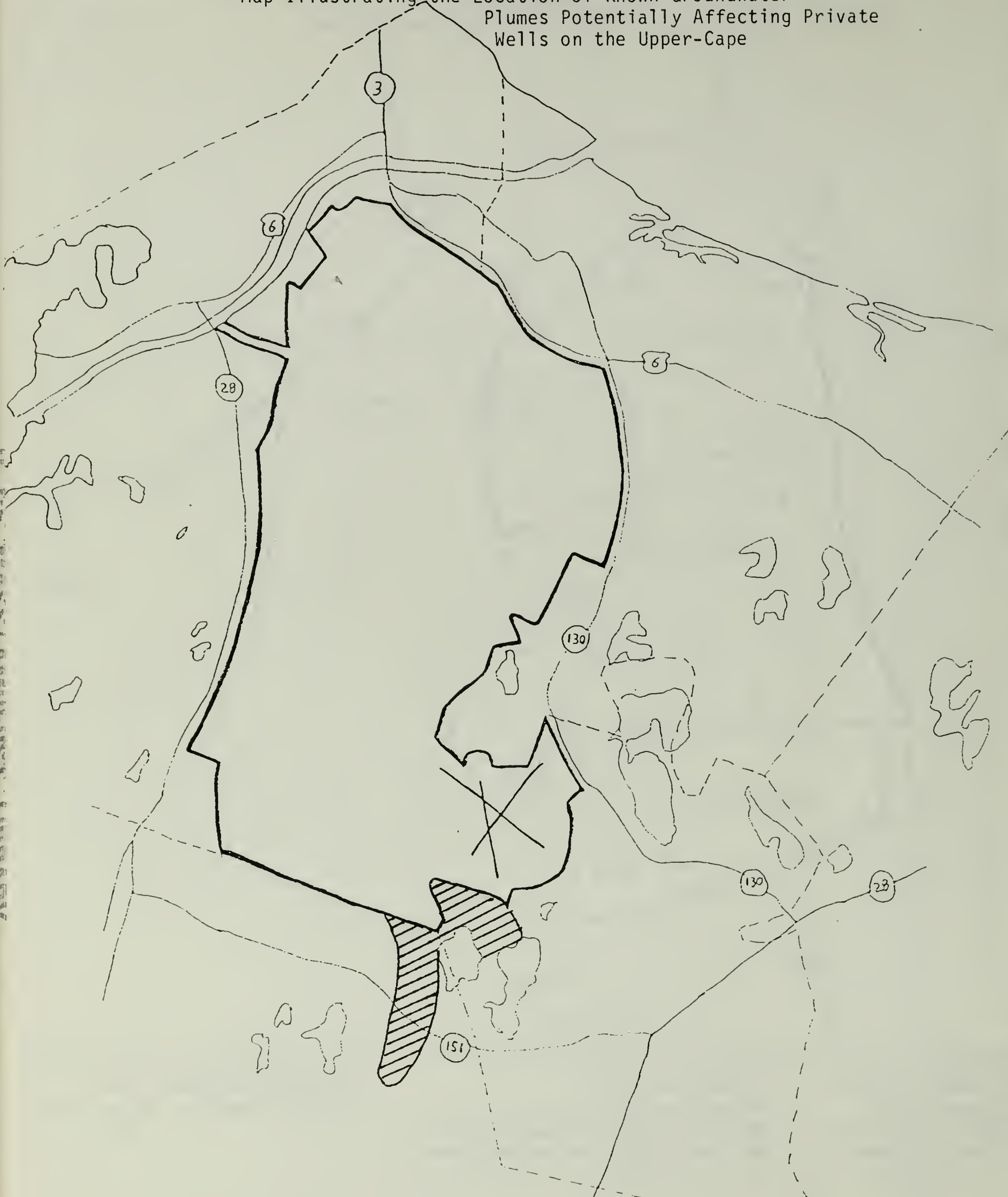


FIGURE 8a:
Map Illustrating Approximate 1970 Population Density For Barnstable

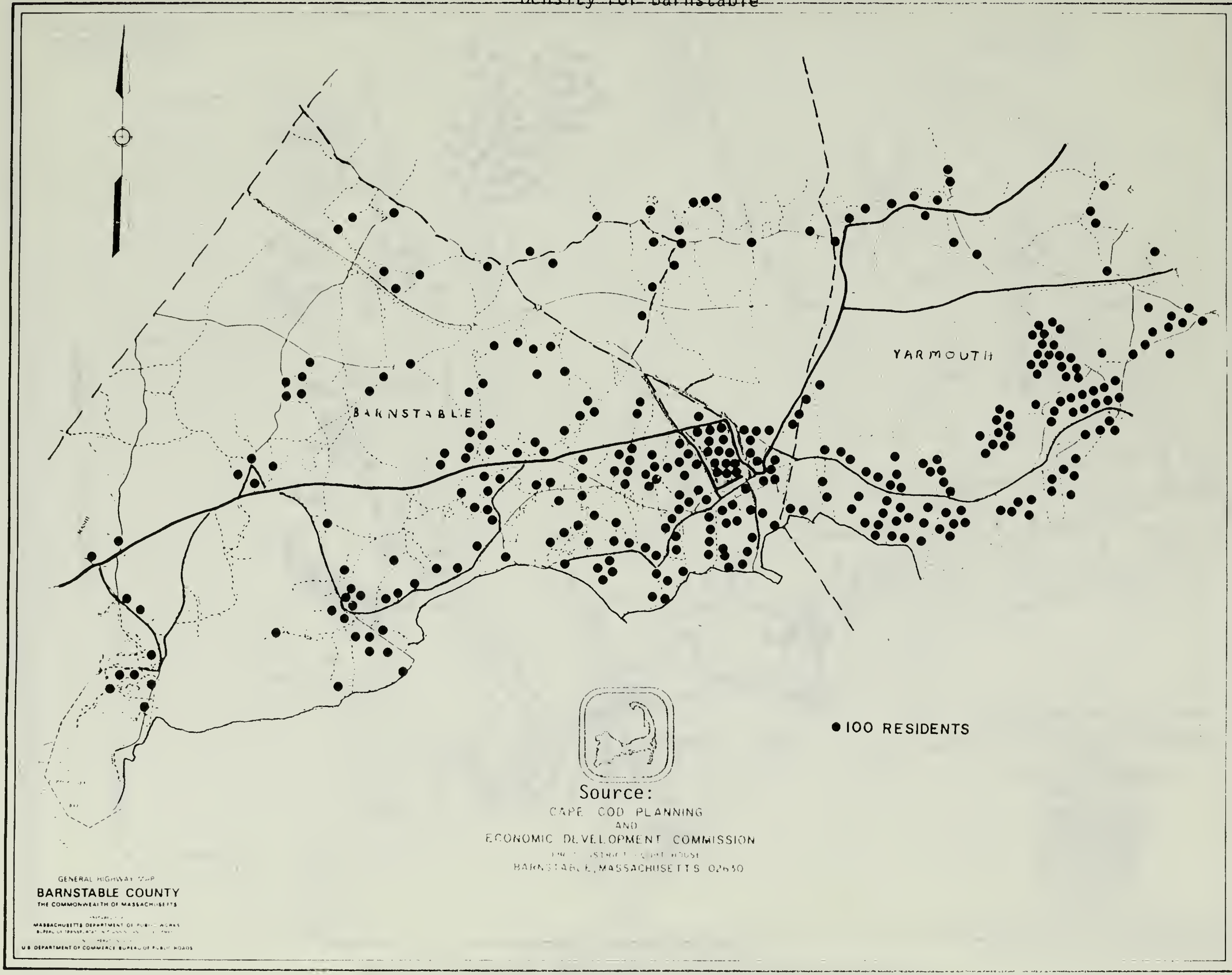


FIGURE 8b:
Map Illustrating Approximate 1970 Population Density
For Bourne and Sandwich

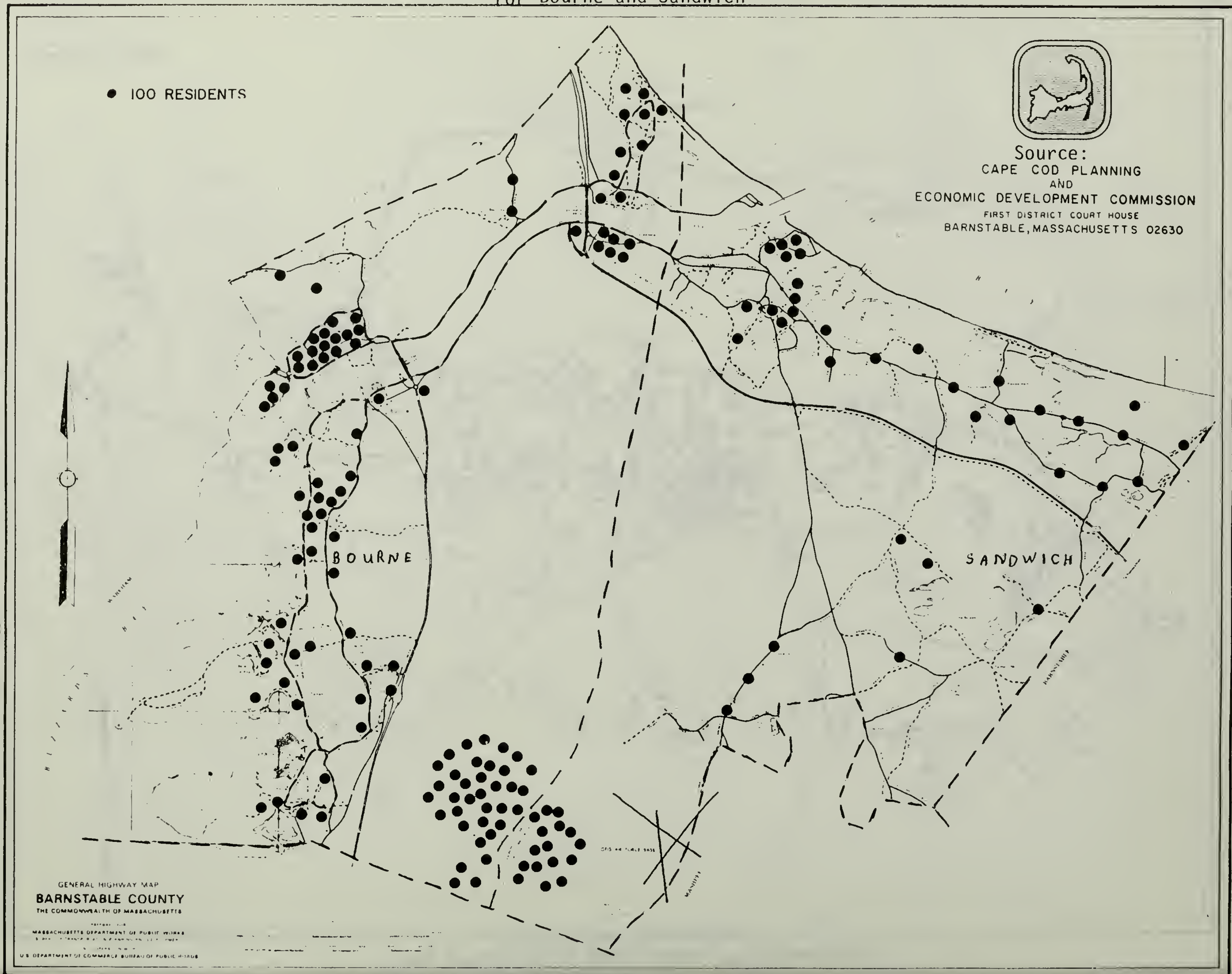
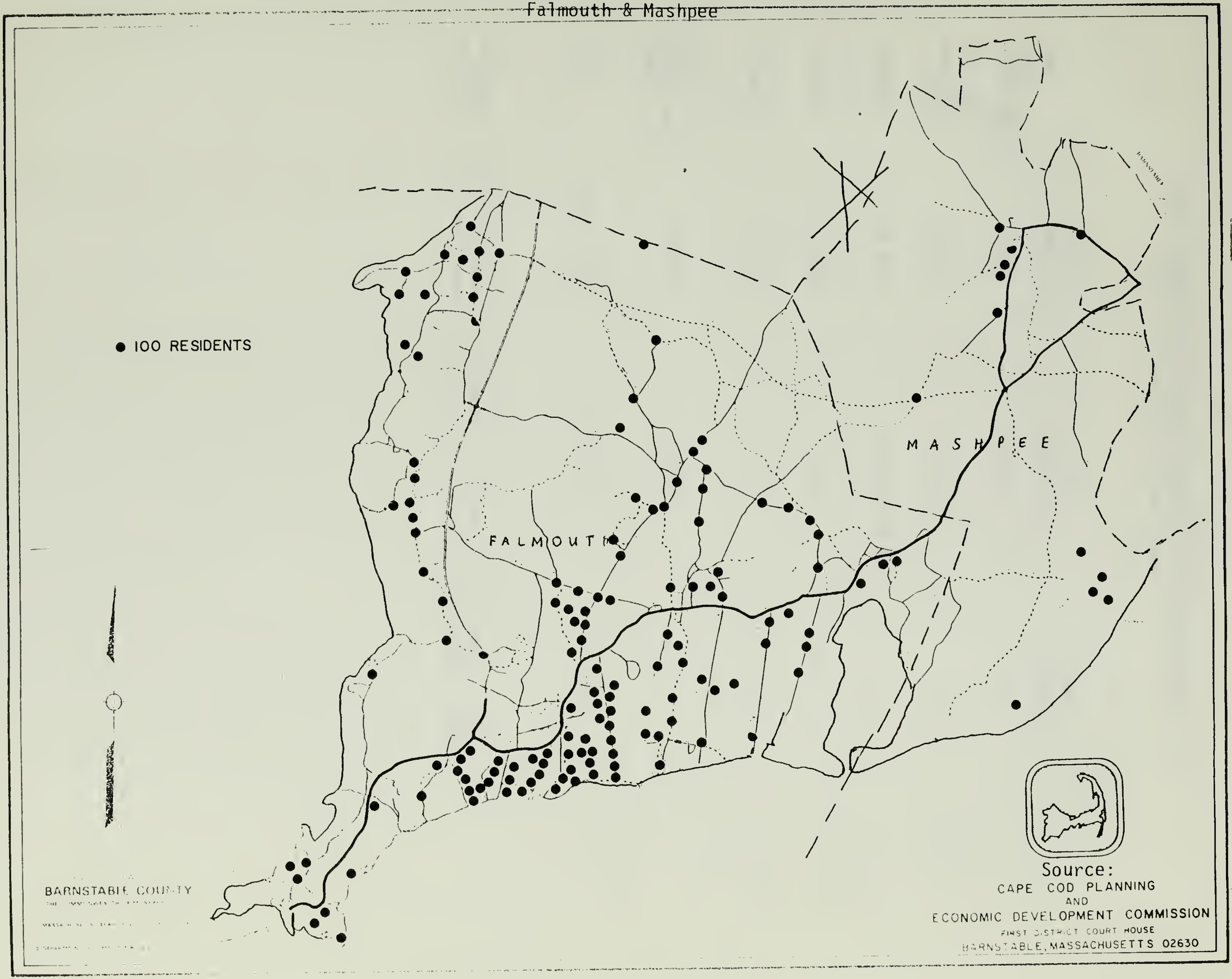


FIGURE 8C:
Map Illustrating Approximate 1970 Population Density for Falmouth & Mashpee



TABLES

Table 1

Percent Population Increase Between 1970 and 1980
for the Five Upper Cape Towns.

Towns	1970 Population*	1980 Population**	Percent Increase
Barnstable	19,842	30,898	55.7
Bourne	12,636	13,874	9.8
Falmouth	15,942	23,640	48.3
Mashpee	1,288	3,700	187.3
Sandwich	5,239	8,727	66.6
Five Upper Cape Towns	54,947	80,839	47.1
State	5,689,170	5,737,037	0.8

*source: U.S. Department of Commerce, Bureau of the Census, 1970
**source: U.S. Department of Commerce, Bureau of the Census, 1980

Table 2

Observed and Expected Numbers of Leukemia and Lung Cancer Deaths, 1969-1983, for the Residents of Bourne.

Cancer Type	Sex	1969-1973 Observed	1969-1973 Expected	1974-1978 Observed	1974-1978 Expected	1979-1983 Observed	1979-1983 Expected
All Cancers	M	65	51.0	71	65.3	76	79.5
	F	49	44.7	62	54.5	84*	64.0
	T	114	95.7	133	119.8	160	143.5
Lung	M	22*	13.8	22	19.0	18	24.0
	F	4	3.6	8	6.0	8	8.8
	T	26	17.4	30	25.0	26	32.8
Leukemia	M	4	2.1	2	2.6	4	2.9
	F	5*	1.7	1	1.9	1	2.1
	T	9*	3.8	3	4.5	5	5.0

*indicates statistically significant excess at .05 Level

Table 3

Observed and Expected Numbers of Leukemia and Lung Cancer Deaths, 1969-1983, for the Residents of Falmouth.

		1969-1973		1974-1978		1979-1983	
Cancer Type	Sex	Observed Deaths	Expected Deaths	Observed Deaths	Expected Deaths	Observed Deaths	Expected Deaths
All Cancers	M	98	91.0	120	126.4	143	160.3
	F	98*	74.7	132*	107.1	176*	138.5
	T	196	165.7	252	233.5	319	298.8
Lung	M	26	25.6	38	37.0	39	48.0
	F	12*	6.1	14	11.8	30*	18.6
	T	38	31.7	52	48.8	69	64.6
Leukemia	M	6	3.4	4	4.7	6	5.5
	F	1	2.6	0	3.5	7	4.6
	T	7	6.0	4	8.2	13	10.1

* indicates statistically significant excess at .05 Level

Table 4

Observed and Expected Numbers of Leukemia and Lung Cancer Deaths, 1969-1983, for the Residents of Mashpee.

		1969-1973		1974-1978		1979-1983	
Cancer Type	Sex	Observed Deaths	Expected Deaths	Observed Deaths	Expected Deaths	Observed Deaths	Expected Deaths
All Cancers	M	4	8.9	19	19.2	26	28.6
	F	2	5.4	13	14.8	14	24.3
	T	6	14.3	32	34.0	40	52.9
Lung	M	1	2.5	5	5.6	10	8.8
	F	2	0.5	2	1.6	3	3.2
	T	3	3.0	7	7.2	13	12.0
Leukemia	M	1	0.3	2	0.7	3	1.0
	F	0	0.2	1	0.5	0	0.8
	T	1	0.5	3	1.2	3	1.8

* indicates statistically significant excess at .05 Level

Table 5

Observed and Expected Numbers of Leukemia and Lung Cancer Deaths, 1969-1983, for the Residents of Sandwich.

		1969-1973		1974-1978		1979-1983	
Cancer Type	Sex	Observed Deaths	Expected Deaths	Observed Deaths	Expected Deaths	Observed Deaths	Expected Deaths
All Cancers	M	25	25.3	40	41.1	60	55.3
	F	21	20.7	35	33.3	55	44.5
	T	46	46.0	75	74.4	115	99.8
Lung	M	8	7.0	13	12.0	23	17.1
	F	2	1.7	3	3.7	7	6.3
	T	10	8.7	16	15.7	30	23.4
Leukemia	M	0	1.0	7*	1.6	2	1.9
	F	0	0.7	0	1.1	4	1.4
	T	0	1.7	7*	2.7	6	3.3

* indicates statistically significant excess at .05 Level

Table 6

Selected Major Sites of Potential Water and Air Contamination on the Upper Cape by Date of Occurrence or Operation, Location of the Site, Nature of the Known or Potential Contamination, and Potential Pathway(s) of Exposure for Residents.

Site	Date of Occurrence or Operation	Location of Site	Nature of Known or Potential Contamination	Potential Pathway(s) of Exposure
Canal Electric Power Plant	1968 to present	Sandwich	Emissions from oil-fired power plant	Air
Mashpee Landfill	1961 to present	Mashpee	Solvents	Groundwater
BOMARC Site	1962 to present	Eastern Boundary of MMR	Solvents, Oil, Hydrazine	Groundwater
Contractors Yard	1954 to 1984	Southeastern Boundary of MMR	Unknown	Groundwater
Fire Training Areas	1948 to 1985	Southern Boundary of MMR	Solvents, Fuel Oil, Transformer Oil	Groundwater Air
Fuel Valve Test Dump	1955 to 1969	Southeastern Area of MMR	Aviation Fuel	Groundwater Air
Johns Pond Dump	Unknown to present	Southeastern of MMR Boundary	Unknown	Groundwater
MMR Landfill	1944 to present	South-Central Area of MMR	Solvents, Fuel, Oil, Pesticide	Groundwater
Propellant Bag Burning Trenches	1936 to present	Various sites in Northern Half of MMR	2,4-Dinitrotoluene	Groundwater Air
Sewage Treatment Plant	1936 to present	Southern Boundary of MMR	VOCs	Groundwater

Table 7. Distribution of Lung Cancer Cases and Controls According to Response Category

	1969-1978		1979-1985	
	Cases # (%)	Controls # (%)	Cases # (%)	Controls # (%)
Residential Histories Not Obtained	16 (20.0)	20 (26.3)	1 (0.8)	8 (6.4)
Subject not Located	15 (93.8)	18 (90.0)	0 (0.0)	1 (12.5)
Subject Refused	1 (6.2)	2 (10.0)	1 (1.0)	7 (5.6)
Residential Histories Obtained	64 (80.0)	56 (73.7)	124 (99.2)	117 (93.6)
Informant Interviewed	63 (98.4)	51 (91.1)	114 (91.9)	106 (90.6)
Histories Obtained from Town Books Only	1 (1.6)	5 (8.9)	10 (8.1)	11 (9.4)
Total	80 (100)	76 (100)	125 (100)	125 (100)

Table 8. Distribution of Leukemia Cases and Controls According to Response Category.

	1969-1978		1979-1985	
	Cases # (%)	Controls # (%)	Cases # (%)	Controls # (%)
Residential Histories Not Obtained	11 (20.0)	12 (21.8)	7 (11.7)	8 (13.3)
Subject not Located	9 (81.8)	11 (91.7)	5 (71.4)	6 (75.0)
Subject Refused	2 (18.2)	1 (8.3)	2 (28.6)	2 (25.0)
Residential Histories Obtained	44 (80.0)	43 (78.2)	53 (88.3)	52 (86.7)
Informant Interviewed	41 (93.2)	42 (97.7)	46 (96.8)	42 (80.8)
Histories Obtained from Town Books Only	3 (6.8)	1 (2.3)	7 (13.2)	10 (19.2)
Total	55 (100)	55 (100)	60 (100)	60 (100)

Table 9. Distribution of Cases and Controls for Whom Residential Histories Were Obtained Through Interview Acccording to the Number of Years Between First Year of Residence on Upper Cape Cod and Death.

Case Series	Number of Years Between First Year of Residence and Death	1969-1978 Cases #	%	Controls #	%	1979-1985 Cases #	%	Controls #	%
Lung Cancer	<10	14	22.2	12	23.5	37	32.5	35	33.0
	10-19	9	14.3	12	23.5	28	24.6	22	20.8
	20+	40	63.5	27	52.9	49	43.0	49	46.2
	Total Interviewed	63	100	51	100	114	100	106	100
Leukemia	<5	12	29.3	9	21.4	5	10.9	8	19.0
	5-09	7	17.1	7	16.7	7	15.2	13	31.0
	10+	22	53.7	26	61.9	34	73.9	21	50.0
	Total Interviewed	41	100	42	100	46	100	42	100

Table 10. Distribution of Cases and Controls for Whom Residential Histories Were Obtained According to the Number of Years Between First Year of Residence on Upper Cape Cod and Death

Case Series	Number of Years Between First Year of Residence and Death	1969-1978 Cases #	%	Controls #	%	1979-1985 Cases #	%	Controls #	%
Lung Cancer	<10	14	21.9	29	29.3	40	32.2	64	37.9
	10-19	9	14.1	20	20.2	31	25.0	38	22.5
	20+	41	64.1	50	50.5	53	42.7	67	39.6
	Total With Residential History	64	100	99*	100	124	100	169**	100
Leukemia	<5	12	27.3	10	10.1	5	9.4	27	26.0
	5-09	7	15.9	19	19.2	9	17.0	37	21.9
	10+	25	56.8	70	70.7	39	73.6	105	62.1
	Total with Residential History	44	100	99*	100	53	100	169**	100

* All lung cancer and leukemia controls from the 1969-1978 series for whom a residential history was obtained

** All lung cancer and leukemia controls from the 1979-1985 series for whom a residential history was obtained

Table 11. Number of Subjects with Complete Residential History Used in Various Case-Control Analyses Relating Death from Lung Cancer to Residence on Upper Cape Cod--by Residence Requirement (Number of Years Since First Year of Residence on Upper Cape Cod); Decade of Death = 1969-1978.

Residence Requirement (Years)	Independent Variable	# of Years Since First Year of Residence	Cases #	Cases %	Controls #	Controls %
10+	Duration of Residence	10+ (used in analysis)	49	77.8	38	74.5
		<10 (disqualified)	14	22.2	13	25.5
		Total interviewed	63	100	51	100
	Exposure (Duration-Distance Formula)	10+ (used in analysis)	49	77.8	36	70.6
		<10 (disqualified)	14	22.2	12	23.5
		Missing Distance	0	0.0	3	5.9
		Total interviewed	63	100	51	100
20+	Duration of Residence	20+ (used in analysis)	40	63.5	27	52.9
		<20 (disqualified)	23	36.5	24	47.1
		Total interviewed	63	100	51	100
	Exposure (Duration-Distance Formula)	20+ (used in analysis)	40	63.5	26	51.0
		<20 (disqualified)	23	36.5	24	47.0
		Missing Distance	0	0.0	1	2.0
		Total interviewed	63	100	51	100

Table 12. Number of Subjects with Complete Residential History Used in Various Case-Control Analyses Relating Death from Lung Cancer to Residence on Upper Cape Cod--by Residence Requirement (Number of Years Since First Year of Residence on Upper Cape Cod); Decade of Death = 1979-1985.

Residence Requirement (Years)	Independent Variable	# of Years Since First Year of Residence	Cases #	Cases %	Controls #	Controls %
10+	Duration of Residence	10+ (used in analysis)	77	67.5	71	67.0
		<10 (disqualified)	37	32.5	35	33.0
		Total interviewed	114	100	106	100
	Exposure (Duration-Distance Formula)	10+ (used in analysis)	77*	67.5	70	66.0
		<10 (disqualified)	37	32.4	35	33.0
		Missing Distance	0*	0.0	1	1.0
		Total interviewed	114	100	106	100
20+	Duration of Residence	20+ (used in analysis)	49	43.0	49	46.2
		<20 (disqualified)	65	57.0	57	53.8
		Total interviewed	114	100	51	100
	Exposure (Duration-Distance Formula)	20+ (used in analysis)	49*	43.0	48	45.2
		<20 (disqualified)	65	57.0	57	53.8
		Missing Distance	0*	0.0	1	1.0
		Total interviewed	114	100	106	100

*The address for one subject was complete enough to ascertain that she had lived farther than ten miles from the canal area and central propellant bag burning sites, but the precise distance of her residence from the fire-training area could not be determined; thus, the total number of subjects used in the case-control analyses is 77 in some analyses using the 10+ years residence requirement and 76 in others; corresponding totals for the 20+ years requirement are 49 and 48.

Table 13. Number of Subjects With Complete Residential History Used in Various Case-Control Analyses Relating Death from Leukemia to Residence on Upper Cape Cod--by Residence Requirement (Number of Years Since First Year of Residence on Upper Cape Cod); Decade of Death = 1969-1978.

Residence Requirement (Years)	Independent Variable	# of Years Since First Year of Residence	Cases #	Cases %	Controls #	Controls %
5+	Duration of Residence	5+ (used in analysis)	29	70.7	33	78.6
		<5 (disqualified)	12	29.3	9	21.4
		Total interviewed	41	100	42	100
	Exposure (Duration-Distance Formula)	5+ (used in analysis)	29	70.7	32	76.2
		<5 (disqualified)	12	29.3	9	21.4
		Missing Distance	0	0.0	1	2.4
		Total interviewed	41	100	42	100
10+	Duration of Residence	10+ (used in analysis)	21	51.2	27	64.3
		<10 (disqualified)	20	48.8	15	35.7
		Total interviewed	41	100	42	100
	Exposure (Duration-Distance Formula)	10+ (used in analysis)	21	51.2	26	61.9
		<10 (disqualified)	20	48.8	15	35.7
		Missing Distance	0*	0.0	1	2.4
		Total interviewed	41	100	42	100

Table 14. Number of Subjects with Complete Residential History Used in Various Case-Control Analyses Relating Death from Leukemia to Residence on Upper Cape Cod--by Residence Requirement (Number of Years Since First Year of Residence on Upper Cape Cod); Decade of Death = 1979-1985.

Residence Requirement (Years)	Independent Variable	# of Years Since First Year of Residence	Cases #	Cases %	Controls #	Controls %
5+	Duration of Residence	5+ (used in analysis)	42	91.3	35	83.3
		<5 (disqualified)	4	8.7	7	16.7
		Total interviewed	46	100	42	100
	Exposure (Duration-Distance Formula)	5+ (used in analysis)	42	91.3	35	83.3
		<5 (disqualified)	4	8.7	7	16.7
		Missing Distance	0	0.0	0	0.0
		Total interviewed	46	100	42	100
10+	Duration of Residence	10+ (used in analysis)	35	76.1	22	52.4
		<10 (disqualified)	11	23.9	20	47.6
		Total interviewed	46	100	42	100
	Exposure (Duration-Distance Formula)	10+ (used in analysis)	35	76.1	22	52.4
		<10 (disqualified)	11	23.9	20	47.6
		Missing Distance	0	0.0	0	0.0
		Total interviewed	46	100	42	100

Table 15. Age Distributions of Cases and Controls Used in the Analysis of the Relationship Between Exposure to the Upper Cape Cod Environment and Risk of Death from Lung Cancer--Data Obtained from Death Certificates for Subjects with Complete Residential Histories who Met the "10+ Years" Residence Requirement.

1969-1978

Age	Cases #	Cases %	Controls #	Controls %
<20	0	0.0	0	0.0
20-44	3	6.1	1	2.8
45-64	19	38.8	18	50.0
65-74	13	26.5	11	30.6
75-84	11	22.4	3	8.3
85+	3	6.1	3	8.3
Total	49	100	36	100

1979-1985

	Cases #	Cases %	Controls #	Controls %
<20	0	0.0	0	0.0
20-44	2	2.6	2	2.8
45-64	29	38.2	24	34.3
65-74	29	38.2	29	41.4
75-84	13	17.1	13	18.6
85+	3	3.9	2	2.8
Total	76	100	70	100

Table 16. Age Distributions of Cases and Controls Used in the Analysis of the Relationship Between Exposure to the Upper Cape Cod Environment and Risk of Death from Lung Cancer--Data Obtained from Death Certificates for Subjects with Complete Residential History who Met the "20+ Years" Residence Requirement.

1969-1978

Age	Cases #	Cases %	Controls #	Controls %
<20	0	0.0	0	0.0
20-44	2	5.0	0	0.0
45-64	16	40.0	13	50.0
65-74	9	22.5	9	34.6
75-84	10	25.0	1	3.8
85+	3	7.5	3	11.5
Total	40	100	26	100

1979-1985

	Cases #	Cases %	Controls #	Controls %
<20	0	0.0	0	0.0
20-44	0	0.0	1	2.1
45-64	19	39.6	17	35.4
65-74	20	40.8	22	45.8
75-84	8	16.7	7	14.6
85+	2	4.2	1	2.1
Total	49	100	48	100

Table 17. Age and Sex Distributions of Cases and Controls Used in the Analysis of the Relationship Between Exposure to the Upper Cape Cod Environment and Risk of Death from Leukemia--Data Obtained from Death Certificates for Subjects with Complete Residential Histories who Met the "5+ Years" Residence Requirement.

1969-1978

Age	Cases #	Cases %	Controls #	Controls %
<20	1	3.4	2	6.2
20-44	3	10.3	0	0.0
45-64	3	10.3	3	9.4
65-74	10	34.4	10	31.2
75-84	10	34.4	13	40.6
85+	2	6.9	4	12.5
Total	29	100	32	100
	% male = 69.0%		% male = 50.0%	

1979-1985

Age	Cases #	Cases %	Controls #	Controls %
<20	1	2.4	1	2.9
20-44	3	7.1	1	2.9
45-64	5	11.9	8	22.8
65-74	14	33.3	12	34.3
75-84	12	28.6	9	25.7
85+	7	16.7	4	11.4
Total	42	100	35	100
	% male = 53.7 %		% male = 58.8%	

Table 18. Age and Sex Distributions of Cases and Controls Used in the Analysis of the Relationship Between Exposure to the Upper Cape Cod Environment and Risk of Death from Leukemia--Data Obtained from Death Certificates for Subjects with Complete Residential Histories who Met the "10+ Years" Residence Requirement.

1969-1978

Age	Cases #	Cases %	Controls #	Controls %
<20	1	4.5	0	0.0
20-44	3	13.6	0	0.0
45-64	2	9.0	3	11.5
65-74	7	31.8	9	34.6
75-84	8	36.4	11	42.3
85+	1	4.5	3	11.5
Total	22	100	26	100
	% male = 72.7%		% male = 53.8%	

1979-1985

Age	Cases #	Cases %	Controls #	Controls %
<20	0	0.0	0	0.0
20-44	3	0.8	1	4.8
45-64	4	11.8	7	33.3
65-74	11	32.4	7	33.3
75-84	9	26.5	4	19.0
85+	7	20.6	2	9.5
Total	34	100	21	100
	% male = 47.0 %		% male = 33.3%	

Table 19. Distribution of Cases and Controls with Complete Residential Histories According to Smoking Status (Ever Smoked).

Leukemia

	1969-78				1979-85			
	Cases		Controls		Cases		Controls	
Smoking Status	#	(%)	#	(%)	#	(%)	#	(%)
Cigarette Smoker	13	31.7	20	47.6	28	60.9	23	54.8
Pipe Smoker	5	12.7	2	4.8	3	6.5	0	0.0
Non-Smoker	22	53.7	18	42.9	15	32.6	19	45.2
Unknown	1	2.4	2	4.8	0	0.0	0	0.0
Total	41	100	42	100	46	100	42	100

Lung Cancer

	1969-78				1979-85			
	Cases		Controls		Cases		Controls	
Smoking Status	#	(%)	#	(%)	#	(%)	#	(%)
Cigarette Smoker	48	76.2	27	52.9	101	88.6	65	61.3
Pipe Smoker	0	0.0	0	0.0	0	0.0	0	0.0
Non-Smoker	15	23.8	21	41.2	13	11.4	38	35.8
Unknown	0	0.0	3	5.9	0	0.0	3	2.8
Total	63	100	51	100	114	100	106	100

Table 20. Mean Packyears for Ever Smokers--Data Obtained by Informant Interview.

	1969-1978		1979-1985	
	Cases	Controls	Cases	Controls
Leukemia	43.8	44.8	52.3	54.3
Lung Cancer	49.4	34.5	60.9	44.9

Table 21. Distribution of Lung Cancer Cases and Controls According to Occupation at Time of Death--Data Obtained from Death Certificates for Those Subjects with Complete Residential Histories.

Occupation Category	1969-1978 Cases #	%	1969-1978 Controls #	%	1979 - 1985 Cases #	%	1979 - 1985 Controls #	%
Clerical/Sales	14	(22.2)	6	(11.8)	13	(11.4)	20	(18.9)
Service*	6	(9.5)	6	(11.8)	19	(16.7)	8	(7.5)
Technical/Professional**	8	(12.7)	6	(11.8)	18	(15.8)	17	(16.0)
Agriculture	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Construction	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Manufacturing	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Chemical Industry	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Homemaker	28	(44.4)	32	(62.7)	60	(52.6)	58	(54.7)
Other	1	(1.6)	0	(0.0)	1	(0.9)	1	(1.0)
Unknown	6	(9.5)	1	(2.0)	3	(2.6)	2	(1.9)
Total	63	(100)	51	(100)	114	(100)	106	(100)

* e.g., police, military, teachers, barbers
** e.g., business managers, engineers, nurses

Table 22. Distribution of Leukemia Cases and Controls According to Occupation at Time of Death--Data from Death Certificates for Those Subjects with Complete Residential Histories.

	1969-1978				1979 -1985			
	Cases		Controls		Cases		Controls	
Occupation Category	#	%	#	%	#	%	#	%
Clerical/Sales	5	(12.2)	1	(2.4)	6	(13.0)	8	(19.0)
Service*	3	(7.3)	5	(11.9)	5	(10.9)	7	(16.7)
Technical/Professional**	5	(12.2)	11	(26.2)	13	(28.3)	13	(31.0)
Agriculture	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Construction	8	(19.5)	7	(16.7)	2	(4.3)	1	(2.4)
Manufacturing	0	(0.0)	1	(2.4)	1	(2.2)	2	(4.8)
Chemical Industry	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Homemaker	12	(29.3)	12	(28.6)	12	(26.1)	9	(21.4)
Other	1	(2.4)	1	(2.4)	3	(6.5)	0	(0.0)
Unknown	7	(17.1)	4	(9.5)	4	(8.7)	2	(4.8)
Total	41	(100)	42	(100)	46	(100)	42	(100)

* e.g., police, military, teachers, barbers
** e.g., business managers, engineers, nurses

Table 23. Distribution of Controls According to Cause of Death--Data Obtained from Death Certificates of Subjects for Whom Residential Histories Were Obtained.

Cause of Death	Lung Cancer 1969-1978 #	%	Lung Cancer 1979-1985 #	%	Leukemia 1969-1978 #	%	Leukemia 1979-1985 #	%
Cancer								
Alone	21	37.5	48	40.0	7	16.3	13	25.0
w/Cardiovascular Disease	0	0.0	2	1.7	0	0.0	0	0.0
w/Cerebrovascular Disease	0	0.0	0	0.0	1	2.3	0	0.0
w/Liver Disease	0	0.0	1	0.8	1	2.3	0	0.0
w/Diabetes Mellitus	0	0.0	2	1.7	0	0.0	0	0.0
w/Liver Disease and Diabetes Mellitus	0	0.0	0	0.0	0	0.0	1	1.9
Cardiovascular Disease								
Alone	15	26.8	24	20.5	14	32.6	16	30.8
w/Cerebrovascular Disease	2	3.6	3	2.6	1	2.3	1	1.9
w/Pulmonary Disease	0	0.0	2	1.7	1	2.3	3	5.8
w/Diabetes Mellitus	1	1.8	2	1.7	1	2.3	0	0.0
Pulmonary Disease								
Alone	0	0.0	4	3.4	2	4.7	3	5.8
w/Liver Disease	0	0.0	0	0.0	0	0.0	1	1.9
Diabetes Mellitus								
Alone	0	0.0	0	0.0	0	0.0	1	1.9
w/Cerebrovascular Disease	1	1.8	1	0.8	0	0.0	0	0.0
w/Cardiovascular	0	0.0	1	0.8	0	0.0	0	0.0
Cerebrovascular Disease	0	0.0	1	0.8	0	0.0	0	0.0
w/Pulmonary and Cardiovascular Disease	0	0.0	1	0.8	0	0.0	0	0.0
Cerebrovascular Disease								
Alone	10	17.8	6	5.1	9	20.9	2	3.8
w/Liver Disease	0	0.0	1	0.8	0	0.0	0	0.0
Liver Disease	0	0.0	5	4.3	0	0.0	0	0.0
Trauma	2	3.6	7	6.0	5	11.6	3	5.8
Other	4	7.1	6	5.1	1	2.3	8	15.4
Total	56	100	117	100	43	100	52	100

Table 24. Distribution According to Cancer Type of Controls Who Died of Cancer--Data Obtained from Death Certificates of Subjects for Whom Residential Histories Were Obtained.

	Lung Cancer						Leukemia					
	1969-1978			1979-1985			1969-1978			1979-1985		
Cause of Death	#	%[a]	%[b]	#	%[a]	%[b]	#	%[a]	%[b]	#	%[a]	%[b]
Breast	3	14.3	5.4	18	34.0	15.4	1	11.1	2.3	4	28.6	7.8
Colorectal	3	14.3	5.4	7	13.2	6.0	3	33.3	7.0	1	7.1	1.9
Female Reproductive	3	14.3	5.4	9	17.0	7.7	0	0.0	0.0	2	14.2	3.8
Pancreas	3	14.3	5.4	4	7.5	3.4	0	0.0	0.0	2	14.2	3.8
Liver	0	0.0	0.0	2	3.8	1.7	1	11.1	2.3	0	0.0	0.0
Stomach	2	9.5	3.6	2	3.8	1.7	0	0.0	0.0	0	0.0	0.0
Lymphoma	1	4.8	1.8	4	7.5	3.4	0	0.0	0.0	1	7.1	1.9
Larynx	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
Brain	1	4.8	1.8	1	1.9	0.8	0	0.0	0.0	1	7.1	1.9
Mouth	1	4.8	1.8	0	0.0	0.0	1	11.1	2.3	0	0.0	0.0
Prostate	0	0.0	0.0	0	0.0	0.0	1	11.1	2.3	1	7.1	1.9
Bladder	1	4.8	1.8	0	0.0	0.0	0	0.0	0.0	1	7.1	1.9
Breast and Bladder	1	4.8	1.8	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
Pancreas, Uterus and Larynx	1	4.8	1.8	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
Unknown	1	4.8	1.8	6	11.3	5.1	2	22.2	4.6	1	7.1	1.9
Total	21	100	37.5	53	100	45.2	9	100	20.8	14	100	26.9

[a]Percent of all control cancer deaths

[b]Percent of all controls in the series

Table 25. Standardized Mortality Ratios Comparing Observed and Expected Numbers of Lung Cancer Deaths for Short- and Long-Term Upper Cape Cod Residents.

1969 - 1978

Residence Requirement (years)	Observed Deaths	Expected Deaths	SMR
<10	17.20	15.23	1.13
10-19	11.21	11.85	0.94
20+	51.59	29.02	1.78*
10+	62.80	40.88	1.54*

1979 - 1985

Residence Requirement (years)	Observed Deaths	Expected Deaths	SMR
<10	41.32	40.36	1.02
10-19	32.00	24.28	1.32
20+	54.68	43.50	1.26*
10+	86.68	67.79	1.28*

*statistically significant at the 0.05 level

Table 26. Standardized Mortality Ratios Comparing Observed and Expected Numbers of Leukemia Deaths for Short- and Long-Term Upper Cape Cod Residents --by Decade of Death.

1969 - 1978

Residence Requirement (years)	Observed Deaths	Expected Deaths	SMR
<5	15.47	4.92	3.14*
5-9	8.88	9.36	0.95
10+	30.65	34.42	0.89
5+	39.53	43.78	0.90

1979 - 1985

Residence Requirement (years)	Observed Deaths	Expected Deaths	SMR
<5	6.34	9.30	0.68
5-9	10.08	12.24	0.82
10+	44.57	33.06	1.35*
5+	54.66	45.30	1.21

* statistically significant of the 0.05 level

Table 27. Distribution of Lung Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to the Canal Electric Plant.

Residence Requirement	Closest Distance(miles)	1969-1978 Cases #	(%)	1969-1978 Controls #	(%)	1979-1985 Cases #	(%)	1979-1985 Controls #	(%)
10+	<0.6	0		0		0		1	
	0.6-1.0	1	(2.0)	1	(2.8)	3	(3.9)	4	(5.7)
	1.1-1.5	0		3	(8.3)	0		1	(1.4)
	1.6-2.0	0		0		0		0	
	2.1-2.5	1	(2.0)	0		1	(1.3)	1	(1.4)
	2.6-3.0	0		0		0		0	
	3.1-4.0	1	(2.0)	0		0		2	(2.9)
	4.1-5.0	0		0		6	(7.8)	3	(4.3)
	>5.0	46	(93.9)	32	(88.9)	67	(87.0)	58	(82.9)
	Total	49	(100)	36	(100)	77	(100)	70	(100)
20+	<0.6	0		0		0		0	
	0.6-1.0	1	(2.5)	0		1	(2.0)	1	(2.1)
	1.1-1.5	0		2	(7.7)	0		1	(2.1)
	1.6-2.0	0		0		0		0	
	2.1-2.5	1	(2.5)	0		0		1	(2.1)
	2.6-3.0	0		0		0		0	
	3.1-4.0	1	(2.5)	0		0		1	(2.1)
	4.1-5.0	0		0		3	(6.1)	2	(4.2)
	>5.0	37	(92.5)	24	(92.3)	45	(91.8)	42	(87.5)
	Total	40	(100)	26	(100)	49	(100)	48	(100)

Table 28. Results of Contingency Table Analyses Relating Distance from Closest Residence to the Canal Electric Plant to Risk of Death from Lung Cancer--Data Obtained by Informant Interview.

Decade of Death	Residence Requirement	Closest Residence (miles)	Cases	Controls	Odds Ratio	95% Confidence Interval
1969-78	10+	≤ 5.0	3	4	0.52	(0.25, 1.08)
		> 5.0	46	32	1.00	
	20+	≤ 5.0	3	2	0.97	(0.26, 4.05)
		> 5.0	37	24	1.00	
1979-85	10+	≤ 5.0	10	12	0.73	(0.47, 1.14)
		> 5.0	67	58	1.00	
	20+	≤ 5.0	4	6	0.62	(0.32, 1.18)
		> 5.0	45	42	1.00	

Table 29. Distribution of Lung Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to the Northeast Propellant Bag Burning Area.

Residence Requirement	Closest Distance(miles)	1969-1978 Cases #	(%)	1969-1978 Controls #	(%)	1979-1985 Cases #	(%)	1979-1985 Controls #	(%)
10+	<0.6	0		0		0		0	
	0.6-1.0	0		0		2	(2.6)	1	(1.4)
	1.1-1.5	0		1	(2.8)	0		4	(5.7)
	1.6-2.0	1	(2.0)	3	(8.3)	1	(1.3)	0	
	2.1-2.5	0		0		1	(1.3)	0	
	2.6-3.0	0		0		1	(1.3)	1	(1.4)
	3.1-4.0	1	(2.0)	1	(2.8)	7	(9.1)	6	(8.6)
	4.1-5.0	6	(12.2)	2	(5.6)	6	(7.8)	4	(5.7)
	>5.0	41	(83.7)	29	(80.6)	59	(76.6)	54	(77.1)
	Total	49	(100)	36	(100)	77	(100)	70	(100)
20+	<0.6	0		0		0		0	
	0.6-1.0	0		0		1	(2.0)	0	
	1.1-1.5	0		0		0		1	(2.1)
	1.6-2.0	1	(2.5)	2	(7.7)	0		0	
	2.1-2.5	0		0		0		0	
	2.6-3.0	0		0		0		1	(2.1)
	3.1-4.0	1	(2.5)	0		4	(8.2)	5	(10.4)
	4.1-5.0	6	(15.0)	1	(3.8)	4	(8.2)	2	(4.2)
	>5.0	32	(80.0)	23	(88.5)	40	(81.6)	39	(81.2)
	Total	40	(100)	26	(100)	49	(100)	48	(100)

Table 30. Results of Contingency Table Analyses Relating Distance from Closest Residence to the Northeast Propellant Bag Burning Area to Risk of Death from Lung Cancer for Interviewed Subjects--Data Obtained by Informant Interview.

Decade of Death	Residence Requirement	Closest Residence (miles)	Cases	Controls	Odds Ratio	95% Confidence Interval
1969-78	10+	≤ 5.0	8	7	0.81	(0.43, 1.51)
		> 5.0	41	29	1.00	
	20+	≤ 5.0	8	3	1.92	(0.41, 10.07)
		> 5.0	32	23	1.00	
1979-85	10+	≤ 5.0	18	16	1.05	(0.64, 1.70)
		> 5.0	59	54	1.00	
	20+	≤ 5.0	9	9	1.00	(0.52, 1.93)
		> 5.0	40	39	1.00	

Table 31. Distribution of Lung Cancer Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to the Northwest Propellant Bag Burning Area.

Residence Requirement	Closest Distance(miles)	1969-1978 Cases #	(%)	1969-1978 Controls #	(%)	1979-1985 Cases #	(%)	1979-1985 Controls #	(%)
10+	<0.6	0		0		0		0	
	0.6-1.0	0		0		0		0	
	1.1-1.5	0		0		0		0	
	1.6-2.0	0		1	(2.8)	5	(6.5)	4	(5.7)
	2.1-2.5	0		1	(2.8)	4	(5.2)	3	(4.3)
	2.6-3.0	4	(8.2)	2	(5.6)	3	(3.9)	4	(5.7)
	3.1-4.0	3	(6.1)	3	(8.3)	3	(3.9)	2	(2.9)
	4.1-5.0	3	(6.1)	0		4	(5.2)	3	(4.3)
	>5.0	39	(79.6)	29	(80.6)	58	(75.3)	54	(77.1)
	Total	49	(100)	36	(100)	77	(100)	70	(100)
20+	<0.6	0		0		0		0	
	0.6-1.0	0		0		0		0	
	1.1-1.5	0		0		0		0	
	1.6-2.0	0		0		0		4	(8.3)
	2.1-2.5	0		0		0		3	(6.2)
	2.6-3.0	4	(10.0)	1	(3.8)	1	(2.0)	1	(2.1)
	3.1-4.0	3	(7.5)	2	(7.7)	2	(4.1)	1	(2.1)
	4.1-5.0	3	(7.5)	0		0		1	(2.1)
	>5.0	30	(75.0)	23	(88.5)	43	(93.9)	38	(79.2)
	Total	40	(100)	26	(100)	49	(100)	48	(100)

Table 32. Results of Contingency Table Analyses Relating Distance from Closest Residence to the Northwest Propellant Bag Burning Area to Risk of Death from Lung Cancer--Data Obtained by Informant Interview

Decade of Death	Residence Requirement	Closest Residence (miles)	Cases	Controls	Odds Ratio	95% Confidence Interval
1969-78	10+	≤ 5.0	10	7	1.06	(0.51, 2.22)
		> 5.0	39	29	1.00	
	20+	≤ 5.0	10	3	2.56	(0.39, 18.92)
		> 5.0	30	23	1.00	
1979-85	10+	≤ 5.0	19	16	1.12	(0.68, 1.88)
		> 5.0	58	54	1.00	
	20+	≤ 5.0	10	10	0.83	(0.53, 1.87)
		> 5.0	46	38	1.00	

Table 33. Distribution of Lung Cancer Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to the West Propellant Bag Burning Area.

Residence Requirement	Closest Distance(miles)	1969-1978 Cases #	(%)	1969-1978 Controls #	(%)	1979-1985 Cases #	(%)	1979-1985 Controls #	(%)
10+	<0.6	0		0		0		0	
	0.6-1.0	0		0		0		0	
	1.1-1.5	0		0		0		0	
	1.6-2.0	2	(4.1)	0		0		1	(1.4)
	2.1-2.5	2	(4.1)	1	(2.8)	2	(2.6)	1	(1.4)
	2.6-3.0	0		0		2	(2.6)	4	(5.7)
	3.1-4.0	5	(10.2)	2	(5.6)	7	(9.1)	5	(7.1)
	4.1-5.0	1	(2.0)	1	(2.8)	5	(6.5)	6	(8.6)
	>5.0	39	(79.6)	32	(88.9)	61	(79.2)	53	(75.7)
	Total	49	(100)	36	(100)	77	(100)	70	(100)
20+	<0.6	0		0		0		0	
	0.6-1.0	0		0		0		0	
	1.1-1.5	0		0		0		0	
	1.6-2.0	2	(5.0)	0		0		0	
	2.1-2.5	2	(5.0)	1	(3.8)	1	(2.0)	1	(2.1)
	2.6-3.0	0		0		2	(4.1)	4	(8.3)
	3.1-4.0	5	(12.5)	0		6	(12.2)	2	(4.2)
	4.1-5.0	0		1	(3.8)	5	(10.2)	6	(12.5)
	>5.0	31	(77.5)	24	(92.3)	35	(71.4)	35	(72.9)
	Total	40	(100)	26	(100)	49	(100)	48	(100)

Table 34. Results of Contingency Table Analyses Relating Distance from Closest Residence to the West Propellant Bag Burning Area to Risk of Death from Lung Cancer--Data Obtained by Informant Interview.

Decade of Death	Residence Requirement	Closest Residence (miles)	Cases	Controls	Odds Ratio	95% Confidence Interval
1969-78	10+	≤ 5.0	10	4	2.05	(0.49, 9.13)
		> 5.0	39	32	1.00	
	20+	≤ 5.0	9	2	3.48	(0.24, 62.76)
		> 5.0	31	24	1.00	
1979-85	10+	≤ 5.0	16	17	0.82	(0.58, 1.40)
		> 5.0	61	53	1.00	
	20+	≤ 5.0	14	13	0.88	(0.49, 1.56)
		> 5.0	35	35	1.00	

Table 35. Distribution of Lung Cancer Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to the South Propellant Bag Burning Area.

		1969-1978				1979-1985			
		Cases		Controls		Cases		Controls	
Residence Requirement	Closest Distance(miles)	#	(%)	#	(%)	#	(%)	#	(%)
10+	<0.6	0		0		0		0	
	0.6-1.0	0		0		0		0	
	1.1-1.5	0		0		0		0	
	1.6-2.0	0		0		0		0	
	2.1-2.5	0		0		0		0	
	2.6-3.0	1	(2.0)	0		0		0	
	3.1-4.0	4	(8.2)	1	(2.8)	3	(3.9)	4	(5.7)
	4.1-5.0	1	(2.0)	2	(5.6)	2	(2.6)	7	(10.0)
	>5.0	43	(87.8)	33	(91.7)	72	(93.5)	59	(84.3)
	Total	49	(100)	36	(100)	77	(100)	70	(100)
20+	<0.6	0		0		0		0	
	0.6-1.0	0		0		0		0	
	1.1-1.5	0		0		0		0	
	1.6-2.0	0		0		0		0	
	2.1-2.5	0		0		0		0	
	2.6-3.0	1	(2.5)	0		0		0	
	3.1-4.0	4	(10.0)	1	(3.8)	1	(2.0)	2	(4.2)
	4.1-5.0	0		2	(7.7)	2	(4.1)	6	(12.5)
	>5.0	35	(87.5)	23	(88.5)	46	(93.9)	40	(83.3)
	Total	40	(100)	26	(100)	49	(100)	48	(100)

Table 36. Results of Contingency Table Analyses Relating Distance from Closest Residence to the South Propellant Bag Burning Area to Risk of Death from Lung Cancer--Data Obtained by Informant Interview.

Decade of Death	Residence Requirement	Closest Residence (miles)	Cases	Controls	Odds Ratio	95% Confidence Interval
1969-78	10+	≤ 5.0	6	3	1.54	(0.40, 6.42)
		> 5.0	43	33	1.00	
	20+	≤ 5.0	5	3	1.10	(0.36, 3.55)
		> 5.0	35	23	1.00	
1979-85	10+	≤ 5.0	5	11	0.38	(0.26, 3.55)
		> 5.0	72	59	1.00	
	20+	≤ 5.0	3	8	0.33	(0.20, 0.53)
		> 5.0	46	40	1.00	

Table 37. Distribution Lung Cancer Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to a Propellant Bag Burning Area.

Residency Requirement	Closest Distance(miles)	1969-1978 Cases #	%	1969-1978 Controls #	(%)	1979-1985 Cases #	(%)	1979-1985 Controls #	(%)
10^+	<0.6	0		0		0		0	
	0.6 - 1.0	0		0		2	(2.6)	1	(1.4)
	1.1 - 1.5	0		1	(2.8)	0		4	(5.7)
	1.6 - 2.0	3	(6.1)	4	(11.1)	6	(7.8)	5	(7.1)
	2.1 - 2.5	2	(5.6)	2	(7.7)	7	(9.1)	3	(4.3)
	2.6 - 3.0	2	(5.6)	1	(2.8)	2	(2.6)	4	(5.7)
	3.1 - 4.0	4	(8.2)	0		3	(3.9)	5	(7.1)
	4.1 - 5.0	2	(5.6)	2	(7.7)	0		3	(4.3)
	>5.0	36	(73.5)	26	(72.2)	57	(74.0)	45	(64.3)
	Total	49	(100)	36	(100)	77	(100)	70	(100)
20^+	<0.6	0		0		0		0	
	0.6 - 1.0	0		0		1	(2.0)	0	
	1.1 - 1.5	0		0		0		1	(2.1)
	1.6 - 2.0	3	(7.5)	2	(7.7)	4	(8.2)	3	(6.3)
	2.1 - 2.5	2	(5.0)	1	(3.8)	4	(8.2)	2	(4.2)
	2.6 - 3.0	2	(5.0)	0		2	(4.1)	4	(8.3)
	3.1 - 4.0	4	(10.0)	0		1	(2.0)	3	(6.3)
	4.1 - 5.0	1	(2.5)	2	(7.7)	0		2	(4.2)
	>5.0	28	(70.0)	21	(80.8)	37	(75.5)	33	(68.8)
	Total	40	(100)	26	(100)	49	(100)	48	(100)

Table 38. Results of Contingency Table Analyses Relating Distance From Closest Residence to a Propellant Bag Burning Area to Risk of Death From Lung Cancer for Subjects with Complete Residential Histories

Decade of Death	Residence Requirement	Closest Residence (miles)	Cases	Controls	Odds Ratio	95% Confidence Interval
1969-78	10+	≤ 5.0	13	10	0.94	0.52, 1.69)
		> 5.0	36	26	1.00	
	20+	≤ 5.0	12	5	1.80	(0.53, 6.40)
		> 5.0	28	21	1.00	
1979-85	10+	≤ 5.0	20	20	0.79	(0.55, 1.14)
		> 5.0	57	45	1.00	
	20+	≤ 5.0	12	25	0.27	(0.32, 0.56)
		> 5.0	37	33	1.00	

Table 39. Distribution of Lung Cases and Controls with Complete Residential Histories According to Distance From Closest Residence to the Fuel Test Valve Dump.

Residence Requirement	Closest Distance(miles)	1969-1978 Cases #	(%)	1969-1978 Controls #	(%)	1979-1985 Cases #	(%)	1979-1985 Controls #	(%)
10+	<0.6	0		0		0		0	
	0.6-1.0	0		0		0		0	
	1.1-1.5	0		0		0		0	
	1.6-2.0	0		0		0		0	
	2.1-2.5	0		0		0		0	
	2.6-3.0	0		0		1	(1.3)	1	(1.4)
	3.1-4.0	0		1	(2.8)	3	(3.9)	0	
	4.1-5.0	0		1	(2.8)	4	(5.2)	4	(5.7)
	>5.0	49	(100.0)	34	(94.4)	69	(89.6)	65	(92.9)
	Total	49	(100)	36	(100)	77	(100)	70	(100)
20+	<0.6	0		0		0		0	
	0.6-1.0	0		0		0		0	
	1.1-1.5	0		0		0		0	
	1.6-2.0	0		0		0		0	
	2.1-2.5	0		0		0		0	
	2.6-3.0	0		0		1	(2.0)	1	(2.1)
	3.1-4.0	0		1	(3.8)	1	(2.0)	0	
	4.1-5.0	0		1	(3.8)	3	(6.1)	2	(4.2)
	>5.0	40	(100.0)	24	(92.3)	44	(89.8)	45	(93.8)
	Total	40	(100)	26	(100)	49	(100)	48	(100)

Table 40. Results of Contingency Table Analyses Relating Distance from Closest Residence to the Fuel Test Valve Dump Area to Risk of Death from Lung Cancer--Data Obtained by Informant Interview.

Decade of Death	Residence Requirement	Closest Residence (miles)	Cases	Controls	Odds Ratio	95% Confidence Interval
1969-78*	10+	≤ 5.0	0	2		
		> 5.0	49	34		
	20+	≤ 5.0	0	2		
		> 5.0	40	24		
1979-85	10+	≤ 5.0	8	5	1.50	(0.53, 4.53)
		> 5.0	69	65	1.00	
	20+	≤ 5.0	5	3	1.74	(0.38, 8.63)
		> 5.0	44	45	1.00	

* 1969-78 Odds Ratios Not Computed because No Cases ≤ 5.0 Miles

Table 41. Distribution of Lung Cancer Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to the Fire Training Areas.

Residence Requirement	Closest Distance(miles)	1969-1978 Cases #	(%)	1969-1978 Controls #	(%)	1979-1985 Cases #	(%)	1979-1985 Controls #	(%)
10+	<0.6	0		0		0		0	
	0.6-1.0	0		0		0		0	
	1.1-1.5	0		0		0		1	(1.4)
	1.6-2.0	0		0		1	(1.3)	0	
	2.1-2.5	0		0		0		0	
	2.6-3.0	0		0		1	(1.3)	0	
	3.1-4.0	1	(2.0)	1	(2.8)	0		5	(7.1)
	4.1-5.0	3	(6.1)	4	(11.1)	6	(7.9)	4	(5.7)
	>5.0	45	(91.8)	31	(86.1)	68	(89.5)	60	(85.7)
	Total	49	(100)	36	(100)	76*	(100)	70	(100)
20+									
	<0.6	0		0		0		0	
	0.6-1.0	0		0		0		0	
	1.1-1.5	0		0		0		1	(2.1)
	1.6-2.0	0		0		1	(2.1)	0	
	2.1-2.5	0		0		0		0	
	2.6-3.0	0		0		0		0	
	3.1-4.0	1	(2.5)	1	(3.8)	0		5	(10.4)
	4.1-5.0	2	(5.0)	4	(15.4)	5	(10.4)	4	(8.3)
	>5.0	37	(92.5)	21	(80.8)	42	(87.5)	38	(79.2)
	Total	40	(100)	26	(100)	48*	(100)	48	(100)

*excludes one case with unknown distance to fire training area

Table 42. Results of Contingency Table Analyses Relating Distance from Closest Residence to the Fire Training Areas to Risk of Death from Lung Cancer--Data Obtained by Informant Interview.

Decade of Death	Residence Requirement	Closest Residence (miles)	Cases*	Controls	Odds Ratio	95% Confidence Interval
1969-78	10+	≤ 5.0	4	5	0.55	(0.11, 2.63)
		> 5.0	45	31	1.00	
	20+	≤ 5.0	3	5	0.34	(0.18, 0.59)
		> 5.0	37	21	1.00	
1979-85	10+	≤ 5.0	8	10	0.71	(0.43, 1.14)
		> 5.0	68	60	1.00	
	20+	≤ 5.0	6	10	0.54	(0.34, 0.86)
		> 5.0	42	38	1.00	

*excludes one case with unknown distance to fire training area

Table 43. Distribution of Leukemia Cases and Controls with Complete Residential Histories According to Distance from Closest Residence to the MMR.

Residence Requirement	Closest Distance(miles)	1969-1978 Cases #	(%)	Controls #	(%)	1979-1985 Cases #	(%)	Controls #	(%)
5+	<0.6	0		3	(10.0)	0		0	
	0.6-1.0	0		0		3	(8.1)	1	(2.9)
	1.1-1.5	1	(4.2)	2	(6.7)	2	(5.4)	3	(8.8)
	1.6-2.0	1	(4.2)	3	(6.7)	1	(2.7)	0	
	2.1-2.5	0		3	(9.4)	1	(2.7)	1	(2.9)
	2.6-3.0	0		0		1	(2.7)	1	(2.9)
	3.1-4.0	2	(8.3)	0		3	(8.1)	1	(2.9)
	4.1-5.0	1	(4.2)	3	(10.0)	5	(13.5)	5	(14.7)
	>5.0	19	(79.2)	18	(60.0)	21	(56.8)	21	(63.6)
	Total	24	(100)	32	(100)	37	(100)	33	(100)
10+	<0.6	0		3	(12.0)	0		0	
	0.6-1.0	0		0		3	(10.0)	0	
	1.1-1.5	1	(5.3)	1	(4.0)	2	(6.7)	3	(14.3)
	1.6-2.0	1	(5.3)	1	(4.0)	1	(3.3)	0	
	2.1-2.5	0		2	(8.0)	1	(3.3)	1	(4.8)
	2.6-3.0	0		0		1	(3.3)	1	(4.8)
	3.1-4.0	1	(5.3)	0		2	(6.7)	0	
	4.1-5.0	1	(5.3)	3	(12.0)	3	(10.0)	3	(14.3)
	>5.0	15	(78.9)	15	(60.0)	17	(56.7)	13	(61.9)
	Total	19	(100)	25	(100)	30	(100)	21	(100)

*excludes cases on mainland side of Cape Cod Canal

Table 44. Results of Contingency Table Analyses Relating Distance from Closest Residence to the MMR to Risk of Death from Lung Cancer--Data Obtained by Informant Interview.

Decade of Death	Residence Requirement	Closest Residence (miles)	Cases*	Controls	Odds Ratio	95% Confidence Interval
1969-78	5+	≤ 5.0	5	12	0.40	(0.25, 0.61)
		> 5.0	19	18	1.00	
	10+	≤ 5.0	4	10	0.40	(0.23, 0.66)
		> 5.0	15	15	1.00	
1979-85	5+	≤ 5.0	16	12	1.33	(0.62, 2.89)
		> 5.0	21	21	1.00	
	10+	≤ 5.0	13	8	1.24	(0.51, 3.03)
		> 5.0	17	13	1.00	

*excludes cases residing on mainland side of Cape Cod Canal

Table 45. Descriptive Statistics for Duration (in Excess of the Residence Requirement) of Residence on the Upper Cape for Lung Cancer Subjects--Data Obtained by Informant Interview.

Residence Requirement	Decade of Death	Subject Status	Mean (S.D.*) (yrs.)	Median (yrs.)	Range (yrs.)
10+ years	1969-1978	Cases	15.67 (09.0)	17.0	0.5-37.0
		Controls	14.80 (10.1)	14.5	0.5-35.0
	1979-1985	Cases	14.56 (11.8)	10.0	0.5-35.0
		Controls	14.25 (11.1)	12.0	0.5-35.0
20+ years	1969-1978	Cases	9.14 (09.0)	9.5	0.5-27.0
		Controls	9.89 (10.1)	11.0	0.5-18.0
	1979-1985	Cases	12.02 (08.6)	11.0	0.5-25.0
		Controls	10.61 (07.8)	10.0	0.5-25.0

* S.D. = Standard Deviation

Table 46. Descriptive Statistics for Duration (in Excess of the Residence Requirement) of Residence on the Upper Cape for Leukemia Subjects--Data Obtained by Informant Interview.

Residence Requirement	Decade of Death	Subject Status	Mean (S.D.*) (yrs.)	Median (yrs.)	Range (yrs.)
5+ years	1969-1978	Cases	11.40 (8.0)	11.0	0.5-20.0
		Controls	13.56 (7.3)	15.0	0.5-21.0
	1979-1985	Cases	11.89 (7.1)	12.0	0.5-20.0
		Controls	9.18 (7.3)	7.0	0.5-20.0
10+ years	1969-1978	Cases	10.64 (5.5)	15.0	0.5-15.0
		Controls	11.09 (5.1)	15.0	0.5-15.5
	1979-1985	Cases	9.68 (5.4)	10.0	0.5-15.5
		Controls	8.62 (5.6)	10.0	0.5-16.0

* S.D. = Standard Deviation

Table 47. Results of Contingency Table Analyses Relating Duration of Residence on Upper Cape Cod to Risk of Death from Lung Cancer--Data Obtained by Informant Interview for Subjects who Met the "10+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of Life Excluded).

1969 - 1978

Duration (Years)	Cases	Controls	O.R.	95% CI
0 - 4.5	6	9	1.00	
5 - 14.5	13	10	1.95	(0.43, 9.08)
15 - 19.5	11	4	4.12	(0.70, 26.50)
20+	19	15	1.90	(0.47, 7.84)
Total	49	38		

Chi-square = 3.34 N.S.

1979 - 1985

Duration (Years)	Cases	Controls	O.R.	95% CI
0 - 4.5	23	21	1.00	
5 - 14.5	19	17	1.02	(0.38, 2.71)
15 - 19.5	6	8	0.68	(0.17, 2.68)
20+	29	25	1.06	(0.44, 2.54)
Total	77	71		

Chi square = 0.54 N.S.

Table 48. Results of Contingency Table Analyses Relating Duration of Residence on Upper Cape Cod to Risk of Death from Lung Cancer--Data Obtained by Informant Interview for Subjects who Met the "20+ Years" Residence Requirement (Residential History Accrued During Last 20 Years of Life Excluded).

1969 - 1978

Duration (Years)	Cases	Controls	O.R.	95% CI
0 - 4.5	13	8	1.00	
5 - 14.5	18	11	1.01	(0.27, 3.74)
15+	9	8	0.69	(0.15, 3.06)
Total	40	27		

Chi-square = 0.44 N.S.

1979 - 1985

Duration (Years)	Cases	Controls	O.R.	95% CI	
0 - 4.5	15	17	1.00		
5 - 9.5	5	7	0.81	(0.17, 3.73)	
10 -19.5	17	15	1.28	(0.43, 3.86)	
20+	12	10	1.36	(0.40, 4.67)	0.3911
Total	49	49			

Chi-square = 2.44 N.S. Trend Chi-square = 0.50 N.S.

Table 49. Results of Contingency Table Analyses Relating Duration of Residence on Upper Cape Cod to Risk of Death from Leukemia--Data Obtained by Informant Interview for Subjects Who Met the "5+ Years" Residence Requirement (Residential History Accrued During Last Five Years of Life Excluded).

1969 - 1978

Duration (Years)	Cases	Controls	O.R.	95% CI
0 - 4.5	10	6	1.00	
5 - 14.5	8	11	0.45	(0.08, 2.08)
15+	11	16	0.41	(0.10, 1.74)
Total	29	33		

Chi-square = 2.43 N.S. Trend Chi-square = 1.36 N.S.

1979 - 1985

Duration (Years)	Cases	Controls	O.R.	95% CI
0 - 4.5	7	13	1.00	
5 - 9.5	11	7	2.92	(0.65, 13.73)
10 -19.5	12	8	2.79	(0.65, 12.44)
20+	12	7	3.18	(0.72, 14.78)
Total	42	35		

Chi square = 5.63 N.S. Trend Chi square = 4.620 (sig. at .05)

Table 50. Results of Contingency Table Analyses Relating Duration of Residence on Upper Cape Cod to Risk of Death from Leukemia--Data Obtained by Informant Interview for Subjects who Met the "10+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of Life Excluded).

1969 - 1978

Duration (Years)	Cases	Controls	O.R.	95% CI
< 5	4	4	1.00	
5-9.5	6	7	0.86	(0.10, 7.03)
10+	11	16	0.69	(0.11, 4.31)
Total	21	27		

Chi-square = 0.25 N.S.

1979 - 1985

Duration (Years)	Cases	Controls	O.R.	95% CI
0 - 4.5	11	7	1.00	
5 -14.5	12	8	0.96	(0.21, 4.27)
15+	12	7	1.09	(0.23, 5.06)
Total	35	22		

Chi-square = 0.30 N.S.

Table 51. Results of Contingency Table Analyses Relating Exposure to the Southern Geographic Grouping of Sites to Risk of Death from Lung Cancer---Data Obtained by Informant Interview for Subjects who Met the "10+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of Life Excluded).

1969 - 1978

Exposure Value	Cases	Controls	O.R.	95% CI
0 - 0.19	22	13	1.00	
0.20 - 0.49	17	12	0.84	(0.27, 2.59)
0.50+	10	11	0.54	(0.16, 1.84)
Total	49	36		

Chi-square = 1.26 N.S.

1979 - 1985

Exposure Value	Cases	Controls	O.R.	95% CI
0 - 0.09	22	19	1.00	
0.10 - 0.24	17	19	0.77	(0.28, 2.09)
0.25 - 0.49	20	17	1.02	(0.38, 2.72)
0.50+	17	15	0.98	(0.35, 2.74)
Total	76*	70		

Chi-square = 0.46 N.S.

*excludes one case with unknown distance to fire training area

Table 52. Results of Contingency Table Analyses Relating Exposure to the Southern Geographic Grouping of Sites to Risk of Death from Lung Cancer---Data Obtained by Informant Interview for Subjects who Met the "20+ Years" Residence Requirement (Residential History Accrued During Last 20 Years of Life Excluded).

1969 - 1978

Exposure Value	Cases	Controls	O.R.	95% CI
0 - 0.19	17	6	1.00	
0.20 - 0.49	12	9	0.47	(0.11, 1.99)
0.25+	11	11	0.35	(0.08, 1.45)
Total	40	26		

Chi-square = 5.58 N.S.

1979 - 1985

Exposure Value	Cases	Controls	O.R.	95% CI
0 - 0.09	11	16	1.00	
0.10 - 0.24	18	17	1.54	(0.50, 4.82)
0.25 - 0.49	13	9	2.10	(0.58, 7.80)
0.50+	6	6	1.45	(0.30, 7.07)
Total	48*	48		

Chi-square = 2.13 N.S.

*excludes one case with unknown distance to fire training area

Table 53. Results of Contingency Table Analyses Relating Exposure to the Central Geographic Grouping of Sites to Risk of Death from Lung Cancer--Data Obtained by Informant Interview for Subjects who Met the "10+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of Life Excluded).

1969 - 1978

Exposure Value	Cases	Controls	O.R.	95% CI
0 - 0.09	12	10	1.00	
0.10 - 0.24	17	8	1.77	(0.46, 6.90)
0.25 - 0.49	9	11	0.68	(0.17, 2.73)
0.50+	11	7	1.31	(0.31, 5.63)
Total	49	36		

Chi-square = 2.80 N.S.

1979 - 1985

Exposure Value	Cases	Controls	O.R.	95% CI
0 - 0.09	25	21	1.00	
0.10 - 0.19	12	12	0.84	(0.28, 2.53)
0.20 - 0.24	11	6	1.54	(0.43, 5.70)
0.25 - 0.49	15	17	0.74	(0.27, 2.02)
0.50+	14	14	0.84	(0.30, 2.39)
Total	77	70		

Chi-square = 1.62 N.S.

Table 54. Results of Contingency Table Analyses Relating Exposure to the Central Geographic Grouping of Sites to Risk of Death from Lung Cancer--Data Obtained by Informant Interview for Subjects Who Met the "20+ Years" Residence Requirement (Last 20 Years of Life Excluded).

1969 - 1978

Exposure Value	Cases	Controls	O.R.	95% CI
<.20	16	7	1.00	
0.10 - 0.24	12	11	0.48	(0.12, 1.87)
.25+	12	8	0.66	(0.15, 2.76)
Total	40	26		

Chi-square = 1.49 N.S.

1979 - 1985

Exposure Value	Cases	Controls	O.R.	95% CI
<.10	16	17	1.00	
0.10 - 0.19	12	11	1.16	(0.34, 3.86)
0.20 - 0.49	15	12	1.33	(0.42, 4.19)
.50+	6	8	0.80	(0.19, 3.33)
Total	49	48		

Chi-square = 0.68 N.S.

Table 55. Results of Contingency Table Analyses Relating Exposure to the Northern Geographic Grouping of Sites to Risk of Death from Lung Cancer--Data Obtained by Informant Interview for Subjects who Met the "10+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of Life Excluded).

1969 - 1978

Exposure Value	Cases	Controls	O.R.	95% CI
< 0.10	11	9	1.00	
0.10 - 0.19	14	7	1.64	(0.39, 7.04)
0.20 - 0.49	14	15	0.76	(0.21, 2.78)
0.50+	10	5	1.64	(0.66, 12.80)
Total	49	36		

Chi-square = 2.30 N.S.

1979 - 1985

Exposure Value	Cases	Controls	O.R.	95% CI
< 0.10	26	22	1.00	
0.10 - 0.24	19	18	0.89	(0.35, 2.30)
0.25 - 0.49	20	19	0.89	(0.47, 1.69)
0.50+	12	11	0.92	(0.30, 2.80)
Total	77	70		

Chi square = 0.12 N.S.

Table 56. Results of Contingency Table Analyses Relating Exposure to the Northern Geographic Grouping of Sites to Risk of Death from Lung Cancer---Data Obtained by Informant Interview for Subjects who Met the "20+ Years" Residence Requirement (Residential History Accrued During Last 20 Years of Life Excluded).

1969 - 1978

Exposure Value	Cases	Controls	O.R.	95% CI
0 - 0.09	15	8	1.00	
0.10 - 0.24	13	14	0.50	(0.13, 1.79)
0.25+	12	4	1.60	(0.32, 8.39)
Total	40	26		

Chi-square = 3.34 N.S.

1979 - 1985

Exposure Value	Cases	Controls	O.R.	95% CI
0 - 0.09	19	20	1.00	
0.10 - 0.19	12	10	1.26	(0.39, 4.11)
0.20 - 0.24	6	9	0.70	(0.18, 2.74)
0.25 - 0.99	6	3	2.10	(0.38, 12.65)
1.0+	6	6	1.05	(0.24, 4.59)
Total	49	48		

Chi square = 1.80 N.S.

Table 57. Results of Contingency Table Analyses Relating Exposure to the MMR to Risk of Death from Leukemia--Data Obtained by Informant Interview for Subjects who Met the "5+ Years" Residence Requirement (Residential History Accrued During Last 5 Years of Life Excluded).

1969 - 1978

Exposure Value	Cases	Controls	O.R.	95% CI
< 0.10	7	4	1.00	
0.10 - 0.24	8	7	0.65	(0.10, 4.21)
0.25 - 0.49	8	6	0.76	(0.15, 3.98)
0.50+	6	15	0.23	(0.04, 1.35)
Total	29	32		

Chi-square = 4.88 N.S. Trend Chi-square = 4.668 (sig. at .05)

1979 - 1985

Exposure Value	Cases	Controls	O.R.	95% CI
< 0.10	7	10	1.00	
0.10 - 0.24	10	8	1.79	(0.38, 8.55)
0.25 - 0.49	8	8	1.43	(0.29, 7.13)
0.50+	17	9	2.70	(0.65, 11.65)
Total	42	35		

Chi-square = 2.60 N.S. Trend Chi-square = 1.932 N.S.

Table 58. Results of Contingency Table Analyses Relating Exposure to the MMR to Risk of Death from Leukemia--Data Obtained by Informant Interview for Subjects who Met the "10+ Years" Residence Requirement (Residential History Accrued During Last 10 Years of life Excluded).

				1969 - 1978
Exposure Value	Cases	Controls	O.R.	95% CI
< 0.10	10	9	1.00	
0.20 - 0.49	6	6	0.90	(0.17, 4.85)
0.50+	5	11	0.41	(0.08, 2.00)
Total	21	26		

Chi-square = 1.79 N.S. Trend Chi-square = 1.79 N.S.

				1979 - 1985
Exposure Value	Cases	Controls	O.R.	95% CI
< 0.20	15	9	1.00	
0.20 - 0.49	7	6	0.70	(0.18, 2.80)
0.50+	13	7	1.11	(0.32, 3.89)
Total	34	22		

Chi-square = 0.43 N.S. Trend Chi-square = 0.14 N.S.

Table 59. Number of Matched Pairs Among Eligible Lung Cancer Cases and Controls After Imposition of the Residence Restrictions for Case-Control Analyses

1969-1978

Residence Requirement	Total Number of Matched Pairs	Number of Eligible Pairs	Percent of Total Pairs	Number of Eligible Cases	Percent of Eligible Cases With Eligible Matched Control
10+ years	80	21	26.3	49	42.9
20+ years	80	10	12.5	40	25.0

1979-1985

Residence Requirement	Total Number of Matched Pairs	Number of Eligible Pairs	Percent of Total Pairs	Number of Eligible Cases	Percent of Eligible Cases With Eligible Matched Control
10+ years	125	39	31.2	77	50.6
20+ years	125	20	16.0	49	40.8

Table 60. Number of Matched Pairs Among Eligible Leukemia Cases and Controls After Imposition of the Residence Restrictions for Case-Control Analyses

1969-1978

Residence Requirement	Total Number of Matched Pairs	Number of Eligible Pairs	Percent of Total Pairs	Number of Eligible Cases	Percent of Eligible Cases With Eligible Matched Control
5+ years	55	16	29.1	29	55.2
10+ years	55	12	21.8	22	54.5

1979-1985

Residence Requirement	Total Number of Matched Pairs	Number of Eligible Pairs	Percent of Total Pairs	Number of Eligible Cases	Percent of Eligible Cases With Eligible Matched Control
5+ years	60	24	40.0	41	58.5
10+ years	60	12	20.0	34	35.3

APPENDIX I

The Commonwealth of Massachusetts
Executive Office of Human Services
Department of Public Health

Bailus Walker, Jr. Ph.D., M.P.H.
COMMISSIONER

150 Tremont Street
Boston 02111

The Center for Health Promotion
and Environmental Disease Prevention

We are writing you at this time to request your cooperation and assistance in a health study of the residents of Cape Cod. This study is expected to contribute to understanding a possible relationship between the environment and disease among the residents of the Cape. Your selection as a participant in this study resulted from the fact that you were identified on a death certificate as the "informant" or the "next of kin" of a former resident of Cape Cod.

Your participation would involve answering a few questions over the telephone regarding where the deceased person had previously lived. This survey should take no longer than ten minutes.

You will be contacted on telephone by a staff member of the Massachusetts Department of Public Health within the next ten days. At that time you will be asked to participate in the study. Please be assured that all information collected will be kept in the strictest confidence under Massachusetts General Law 24A. No use will be made of the information that would identify you or the deceased person to anyone outside the project.

The success of the project depends upon obtaining information from everyone contacted. Your cooperation in the survey is important and will be greatly appreciated. If you have any questions about the survey, you may contact me at (617) 727-2662.

Many thanks in advance for assisting us in this effort.

Sincerely,

Robert S. Knorr, Ph.D.
Chief, Environmental
Epidemiology Unit

APPENDIX II

ID #: STATUS: Completed _____

123 45 6789

To Call Back at ______________

Phone #: day time AM/PM

Other (Explain)

SUBJECT:

INFORMANT:

LOG OF CALLS

INTERVIEWER:

mo	day	date	time	AM/PM

mo	day	date	time	AM/PM

mo	day	date	time	AM/PM

mo	day	date	time	AM/PM

INTERVIEW DATE:

mo	day	date	time	AM/PM

10 11 12 13 14 15

This is ________________________________ from the Mass. Dept. of Public Health. I am trying to reach .

IF INFORMANT IS NOT HOME, ASK WHAT WOULD BE A GOOD TIME TO REACH HIM/HER AND RECORD DAY/TIME BELOW.

Alternate interview time: ________________________

day time AM/PM

This concerns . We sent you a letter recently regarding a health study of Cape Cod residents. Did you receive the letter?

IF STUDY SUBJECT IS NOT FAMILIAR WITH CONTENTS OF LETTER, GO TO 1 BELOW, OTHERWISE, CONTINUE READING.

Would you mind helping us by answering a few brief questions? It will take about ten minutes of your time.

IF SUBJECT IS UNWILLING TO COOPERATE, GO TO 2 BELOW, OTHERWISE, BEGIN INTERVIEW.

(1) Well, the Mass. Department of Public Health is conducting a study to help us understand the relationship between the environment and disease among Cape Cod residents. You were selected, because you were identified on a death certificate as the "informant" or "next of kin" of the deceased, , and we need some information about . The details you provide will be kept in strictest confidence, and no use will be made of the information that would identify you or the deceased to anyone outside the project. So, would you mind helping us by answering a few questions? The entire interview should be completed within ten minutes.

IF STUDY SUBJECT IS UNWILLING TO COOPERATE, GO TO 2 BELOW, OTHERWISE, BEGIN INTERVIEW (Page 4).

(2) Well, is there a more convenient time when I can call you back? It's really important, and it will take just a few minutes of your time.

IF SUBJECT REMAINS UNWILLING TO COOPERATE, THANK HIM AND TERMINATE THE INTERVIEW, OTHERWISE, RECORD ALTERNATE TIME HERE________________________

mo day AM/PM

INTERVIEW

O.K. Our records indicate that died in 19. Does that sound correct?

Yes/No/Comments:

16

And at that time was residing at ?

Yes/No/Comments:

17

RECORD ALL RESIDENTIAL INFORMATION ON PAGE 5. CONTINUE UNTIL THE INFORMANT CEASES TO REMEMBER OR UNTIL 20 YEARS HAVE BEEN ACCOUNTED FOR. IF, AT ANY TIME, INFORMANT FAILS TO REMEMBER, ASK HIM/HER TO SUGGEST ANOTHER CONTACT WHO MIGHT SUPPLY THE NEEDED INFORMATION.

Name of alternate informant:

Street Address: City:

State: Telephone #:

subject's address | years of occupancy

death address

street:

city:

state:

And, can you remember where he/she lived before that?

street:

city:

state:

And, can you remember where he/she lived before that?

street:

city:

state:

And, can you remember where he/she lived before that?

street:

city:

state:

And, can you remember where he/she lived before that?

street:

city:

state:

REMEMBER TO RETURN TO PAGE 2 AND RECORD INFORMATION ON AN ALTERNATE INFORMANT IF THE RESPONDANT CANNOT PROVIDE A COMPLETE RESIDENTIAL HISTORY.

SMOKING HISTORY

O.K., we're almost finished. Now, I just need to ask you about 's smoking history. Do you recall whether he/she was a smoker?

Yes/No/Comments:

18

IF SUBJECT NEVER SMOKED, GO TO (3) ON PAGE 6 TO TERMINATE INTERVIEW.

And could you estimate how many packs of cigarettes per day he/she smoked?

#packs per day:_________

19 20

IF THE INFORMANT CANNOT ESTIMATE PACKS PER DAY SMOKED, ASK QUESTION (4) BELOW, OTHERWISE, CONTINUE READING.

(1) And do you remember whether ever quit smoking?

Quit/Didn't Quit/Comments:

21

(2) So, how long all together would you say smoked?

#years smoked __________

22 23

(3) O.K. then, I think I have all the information I need. Thanks so much for helping us out.

TERMINATE INTERVIEW HERE

(4) Well, would you classify him/her as a heavy smoker?

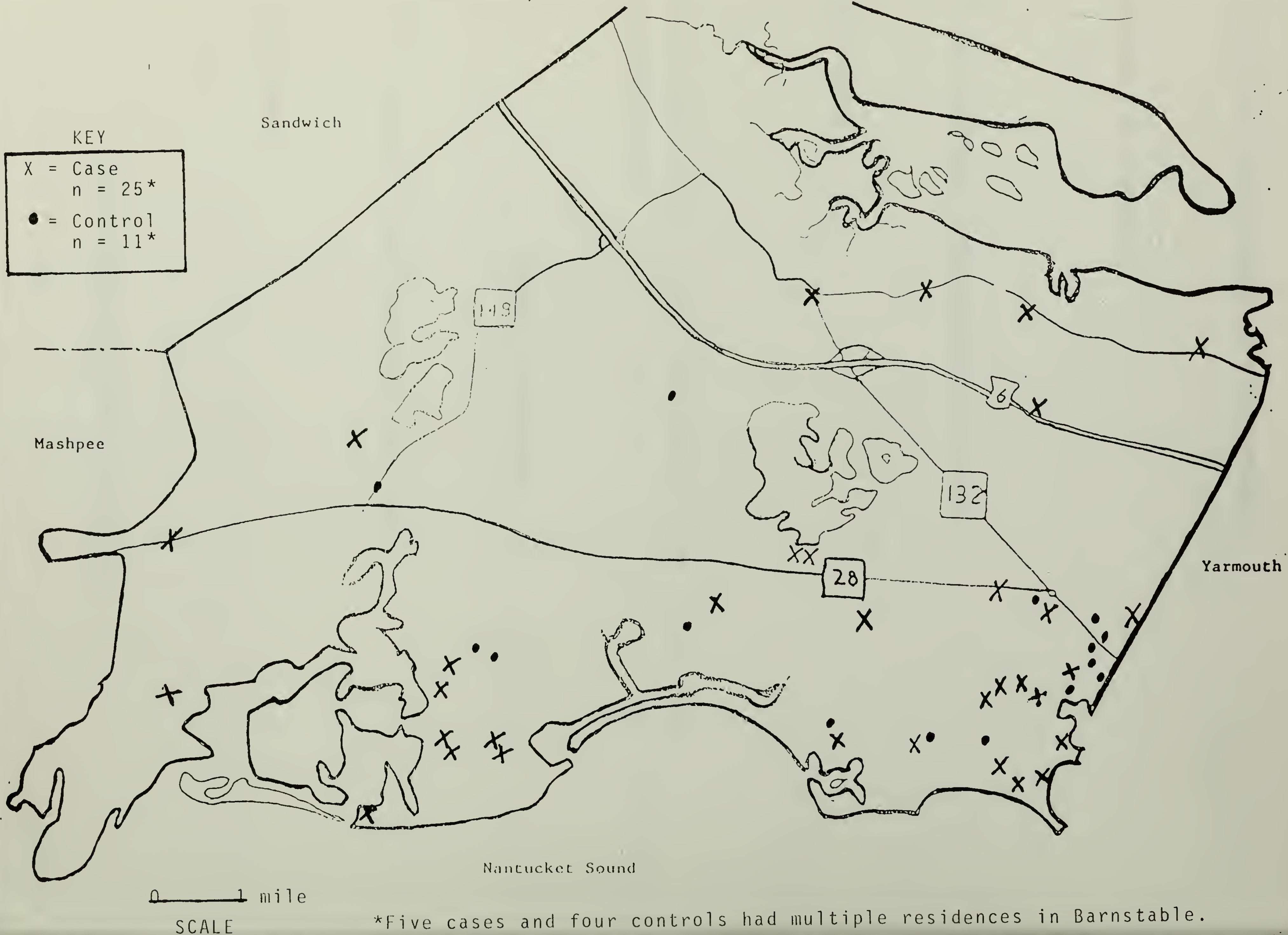
Yes/No/Comments:

19

GO BACK AND ASK QUESTIONS (1) AND (2) NOW.

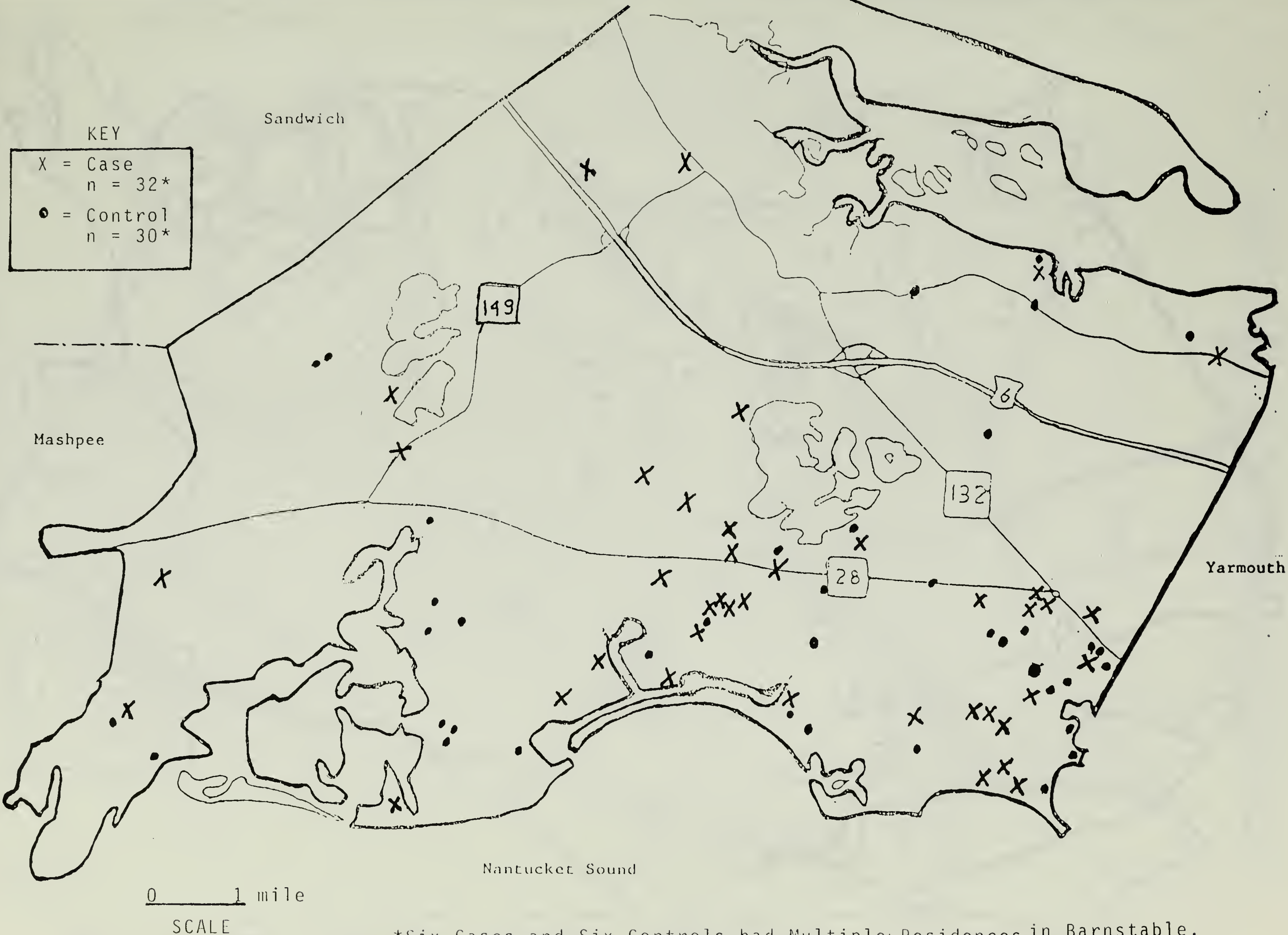
APPENDIX III

Map 1. Locations in Barnstable of Residences Occupied by Cases and Controls who Met the "10+ Years" Residence Requirement--1969-1978 Lung Cancer Series.



*Five cases and four controls had multiple residences in Barnstable.

Map 2. Locations in Barnstable of Residences Occupied by Cases and Controls who Met the "10+ Years" Residence Requirement--1979-1985 Lung Cancer Series.

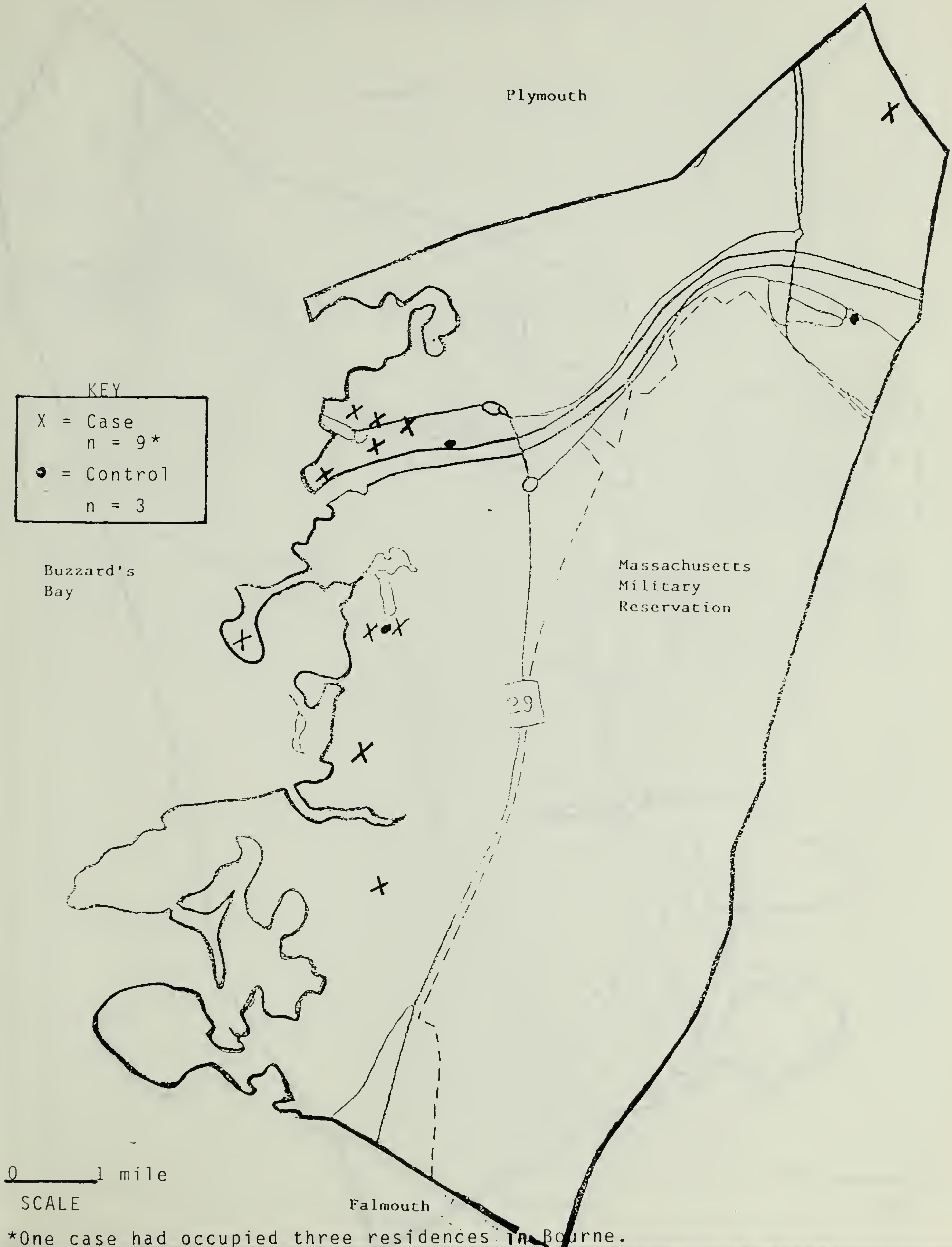


*Six Cases and Six Controls had Multiple Residences in Barnstable.

Map 3. Locations in Barnstable of Residences Occupied by Cases and Controls who Met the "5+ Years" Residence Requirement--1969-1985 Leukemia Series.

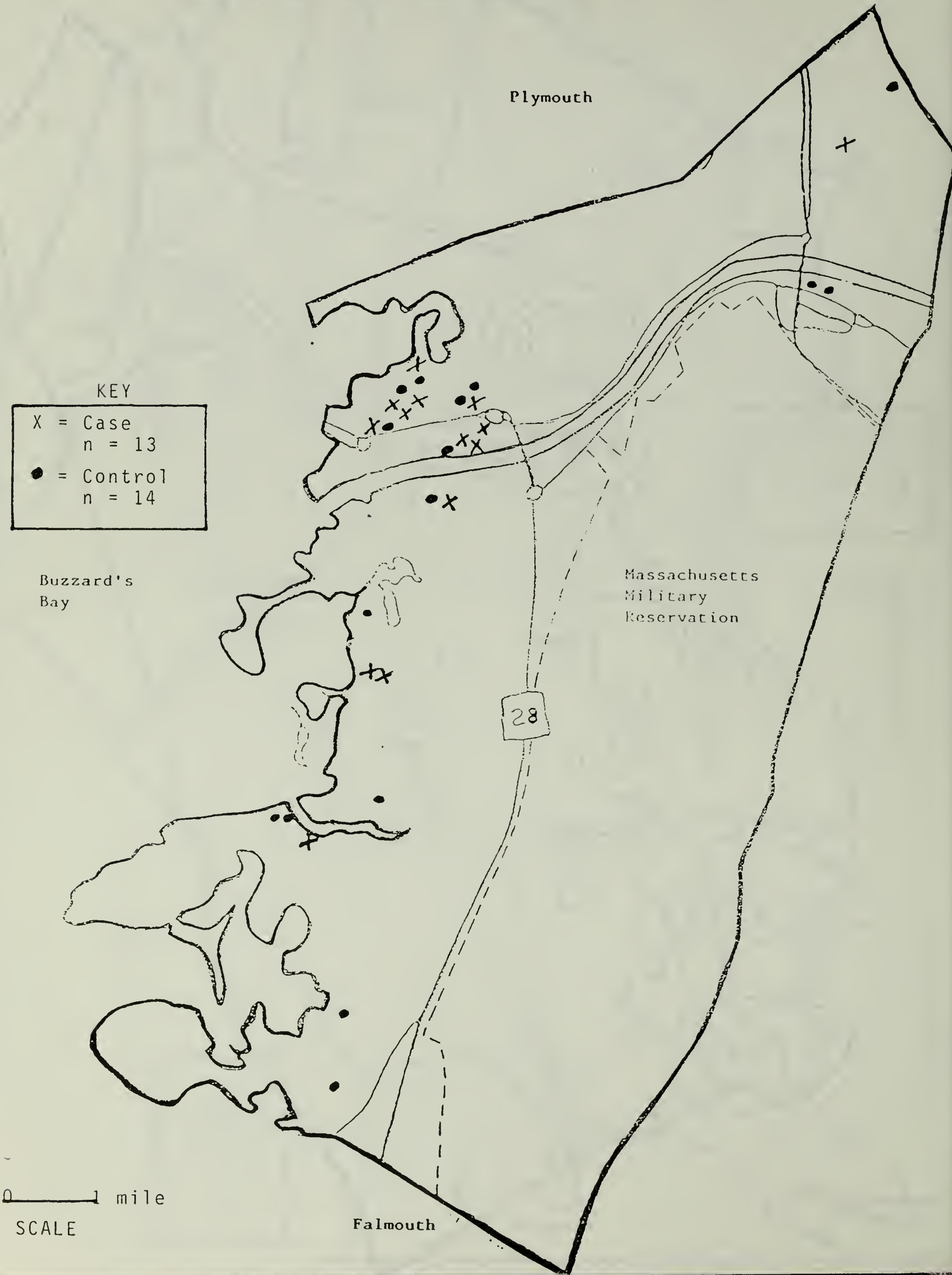
*Eight cases and nine controls had multiple residences in Barnstable.

Map 4. Locations in Bourne of Residences Occupied by Cases and Controls who Met the "10+ Years" Residence Requirement-- 1969-1978 Lung Cancer Series.

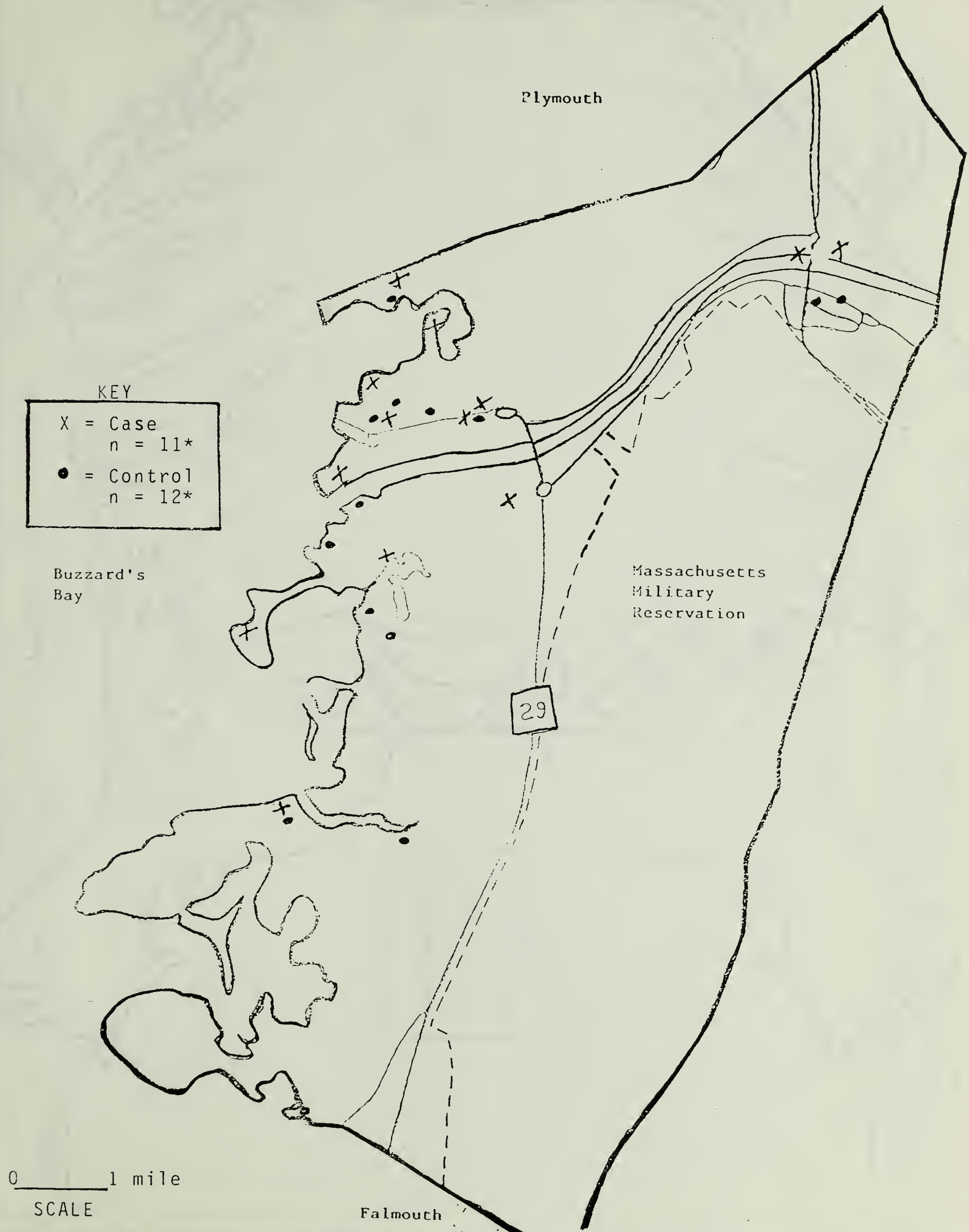


*One case had occupied three residences in Bourne.

Map 5. Locations in Bourne of Residences Occupied by Cases and Controls who Met the "10+ Years" Residence Requirement-- 1979-1985 Lung Cancer Series.

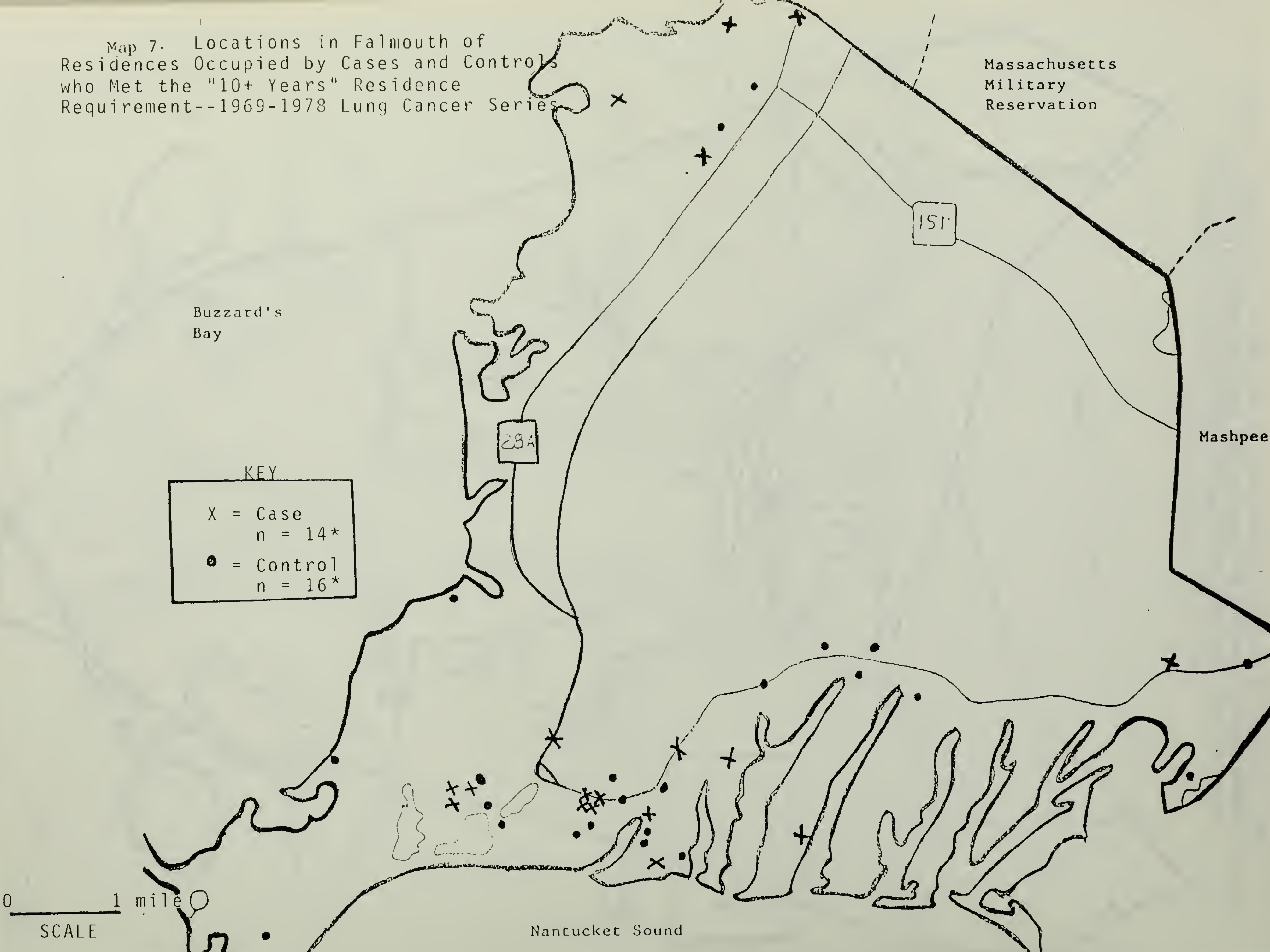


Map 6. Locations in Bourne of Residences Occupied by Cases and Controls who Met the "5+ Years" Residence Requirement-- 1969-1985 Leukemia Series.



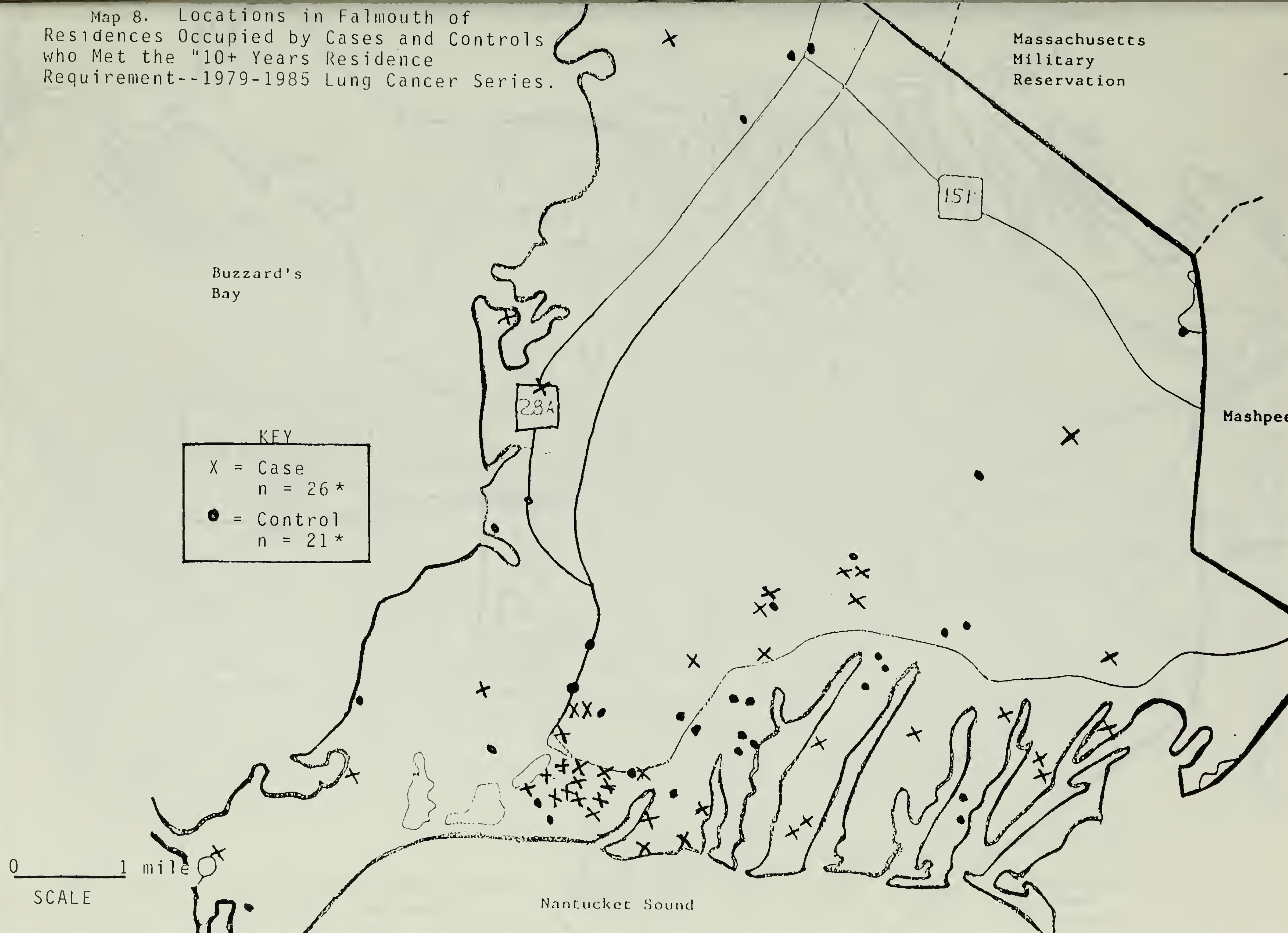
*One case and 2 controls had occupied multiple residences in Bourne

Map 7. Locations in Falmouth of Residences Occupied by Cases and Controls who Met the "10+ Years" Residence Requirement--1969-1978 Lung Cancer Series



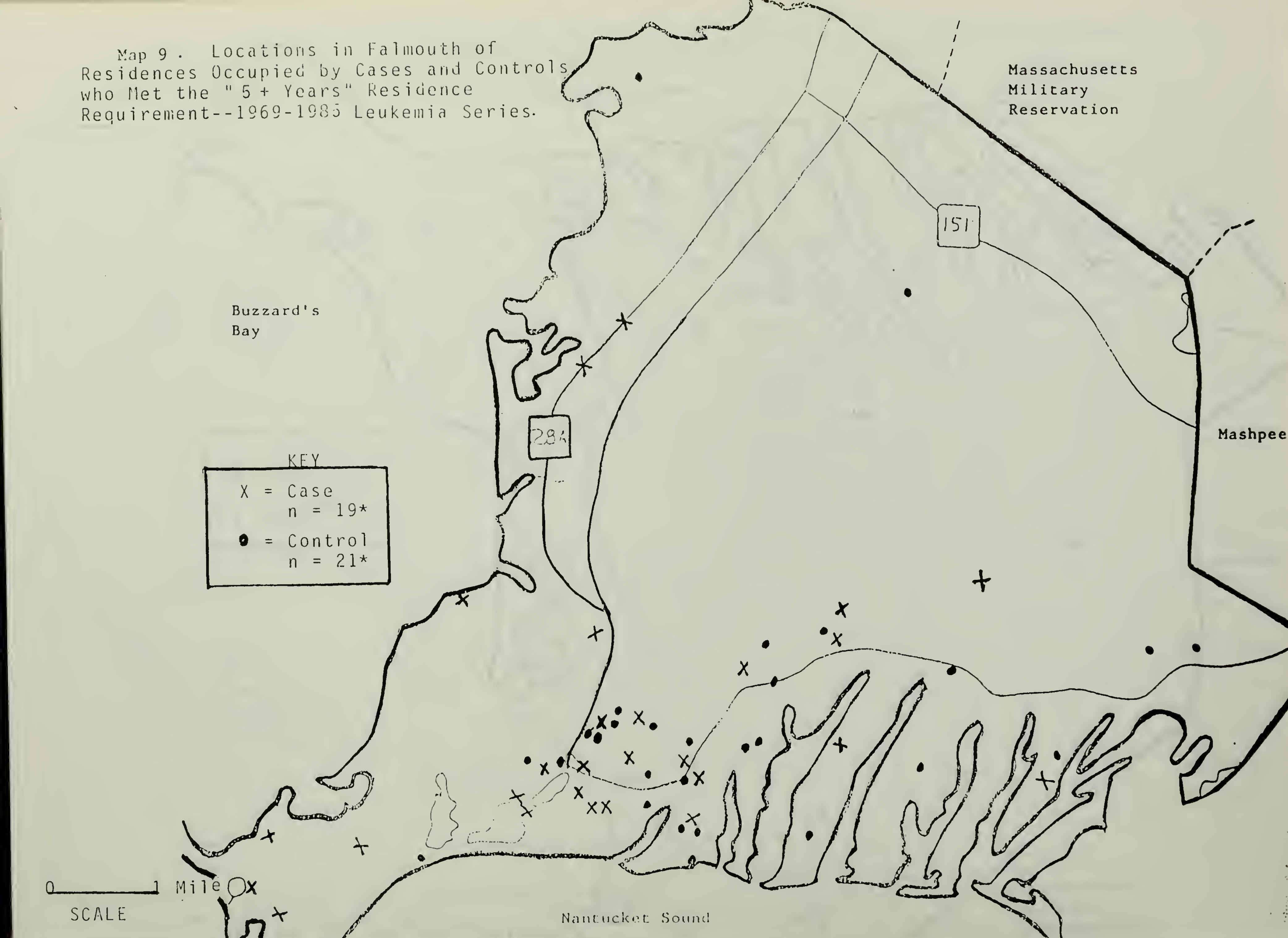
*Four cases and six controls had multiple residences in Falmouth.

Map 8. Locations in Falmouth of Residences Occupied by Cases and Controls who Met the "10+ Years Residence Requirement--1979-1985 Lung Cancer Series.



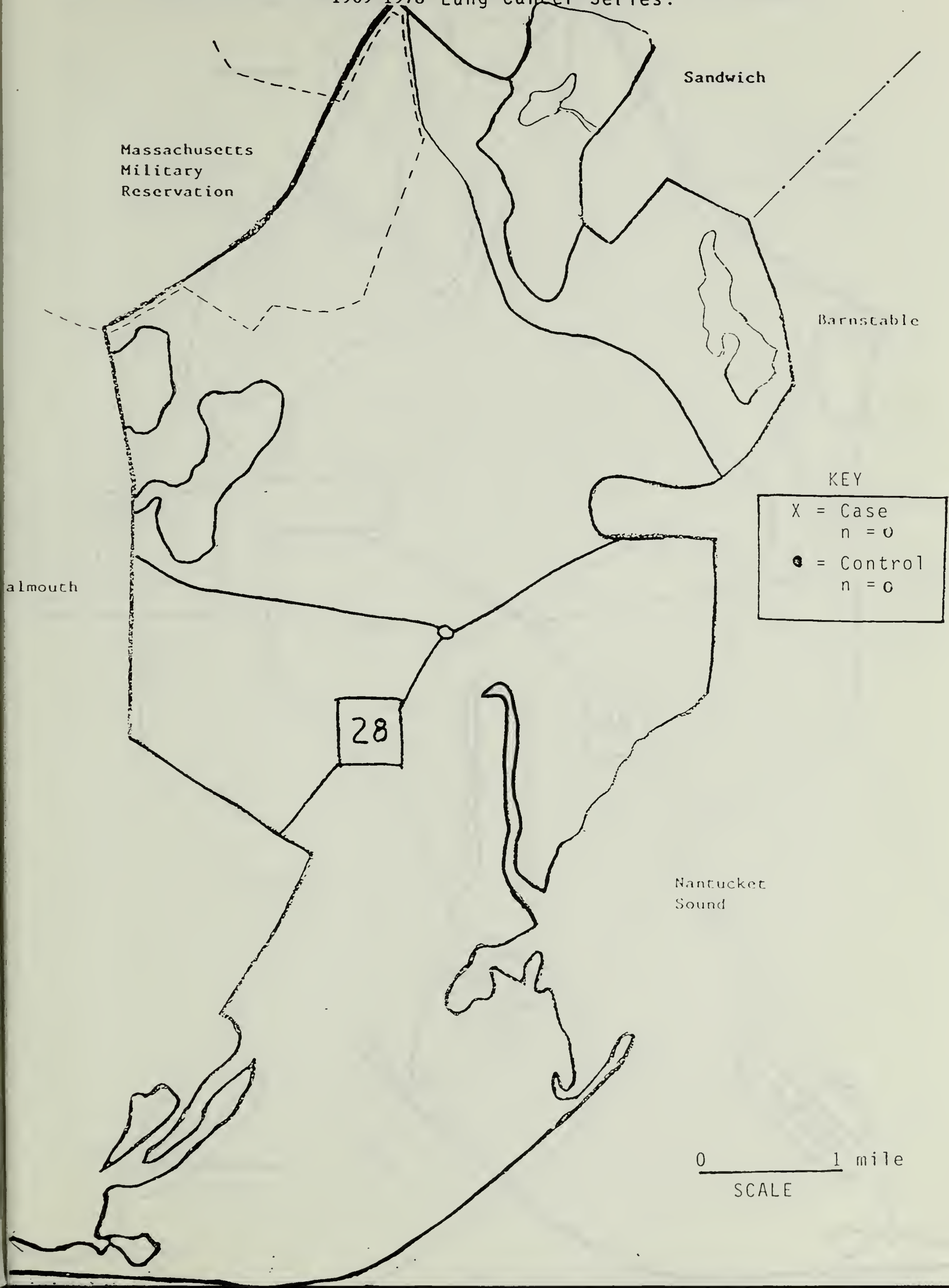
*Ten cases and seven controls had multiple residences in Falmouth.

Map 9. Locations in Falmouth of Residences Occupied by Cases and Controls who Met the "5+ Years" Residence Requirement--1969-1985 Leukemia Series.

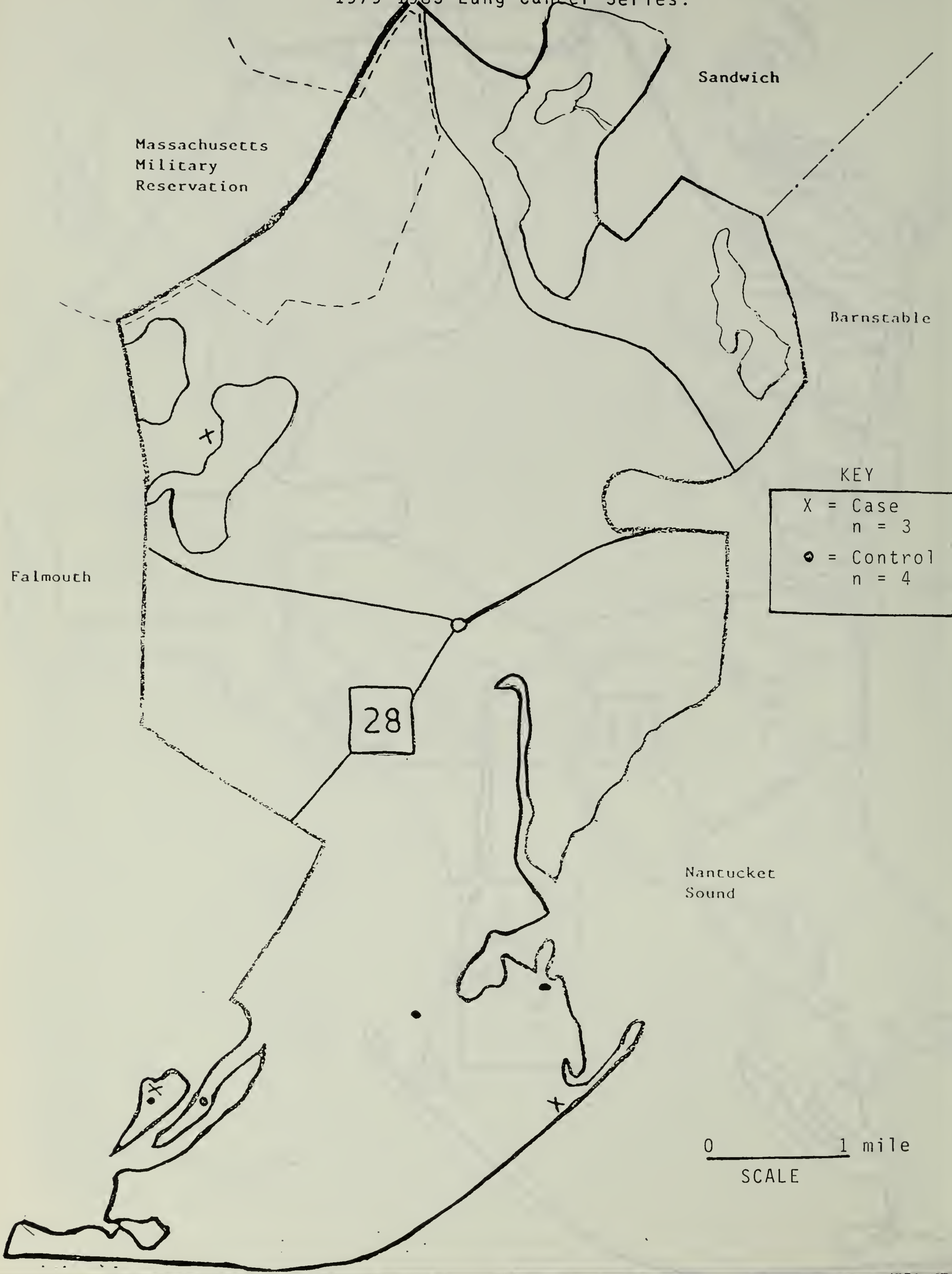


*Six cases and two controls had multiple residences in Falmouth.

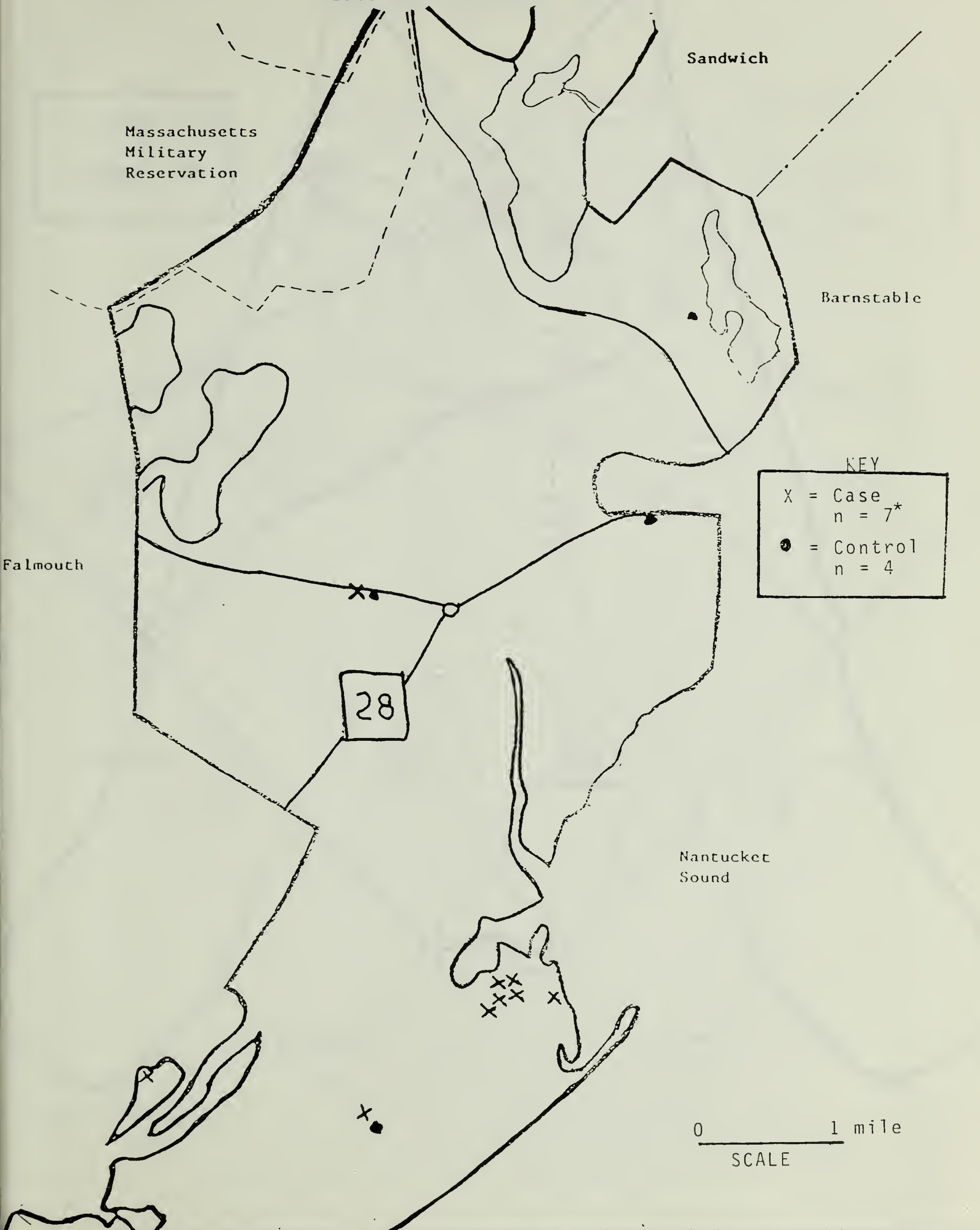
Map 10 - Locations in Mashpee of Residences Occupied by Cases and Controls who Met the "10+ Years" Residence Requirement-- 1969 1978 Lung Cancer Series.



Map 11. Locations in Mashpee of Residences Occupied by Cases and Controls who Met the "10+ Years" Residence Requirement-- 1979-1985 Lung Cancer Series.

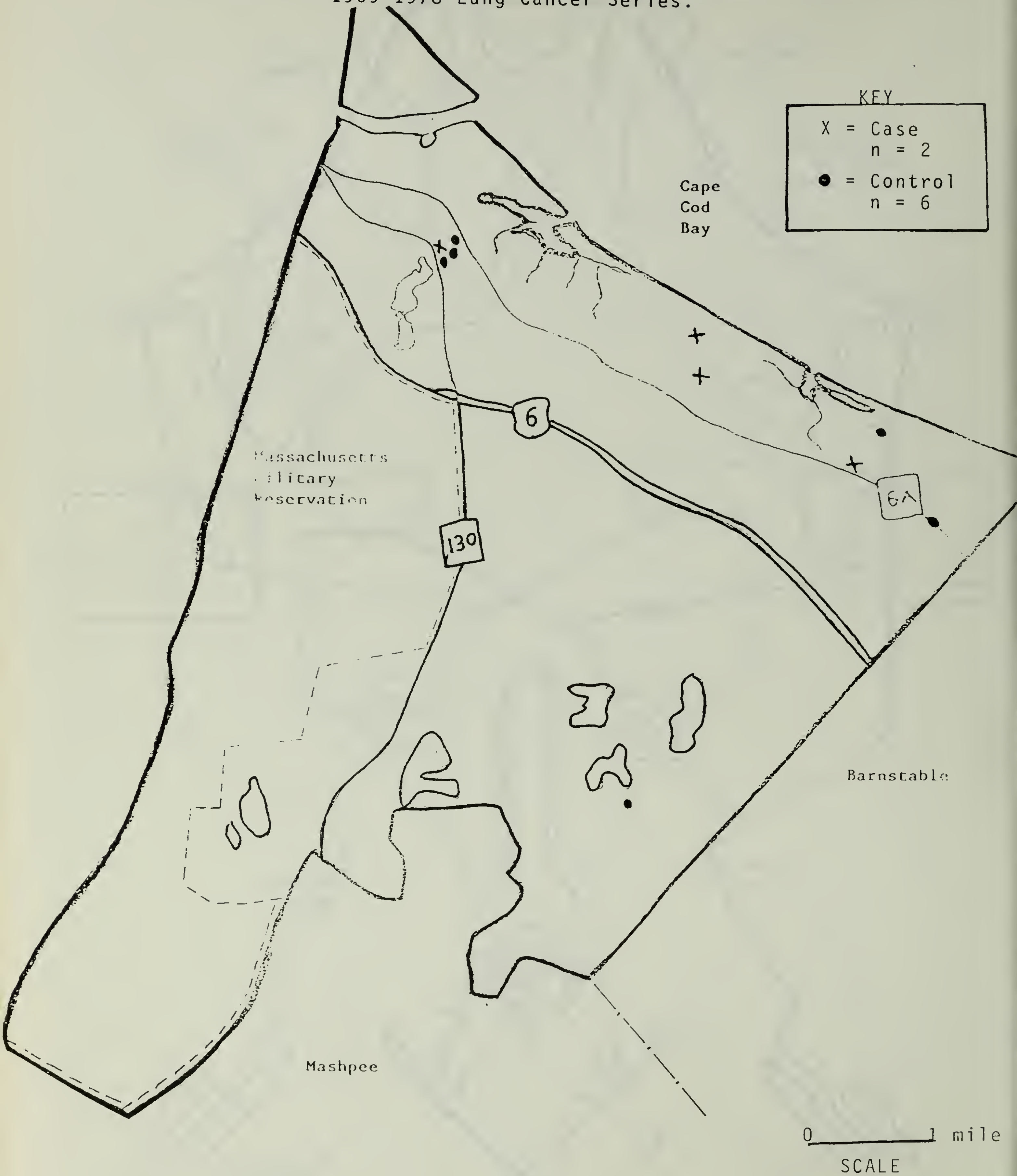


Map 12. Locations in Mashpee of Residences Occupied by Cases and Controls who Met the "5+ Years" Residence Requirement-- 1969-1985 Leukemia Series.

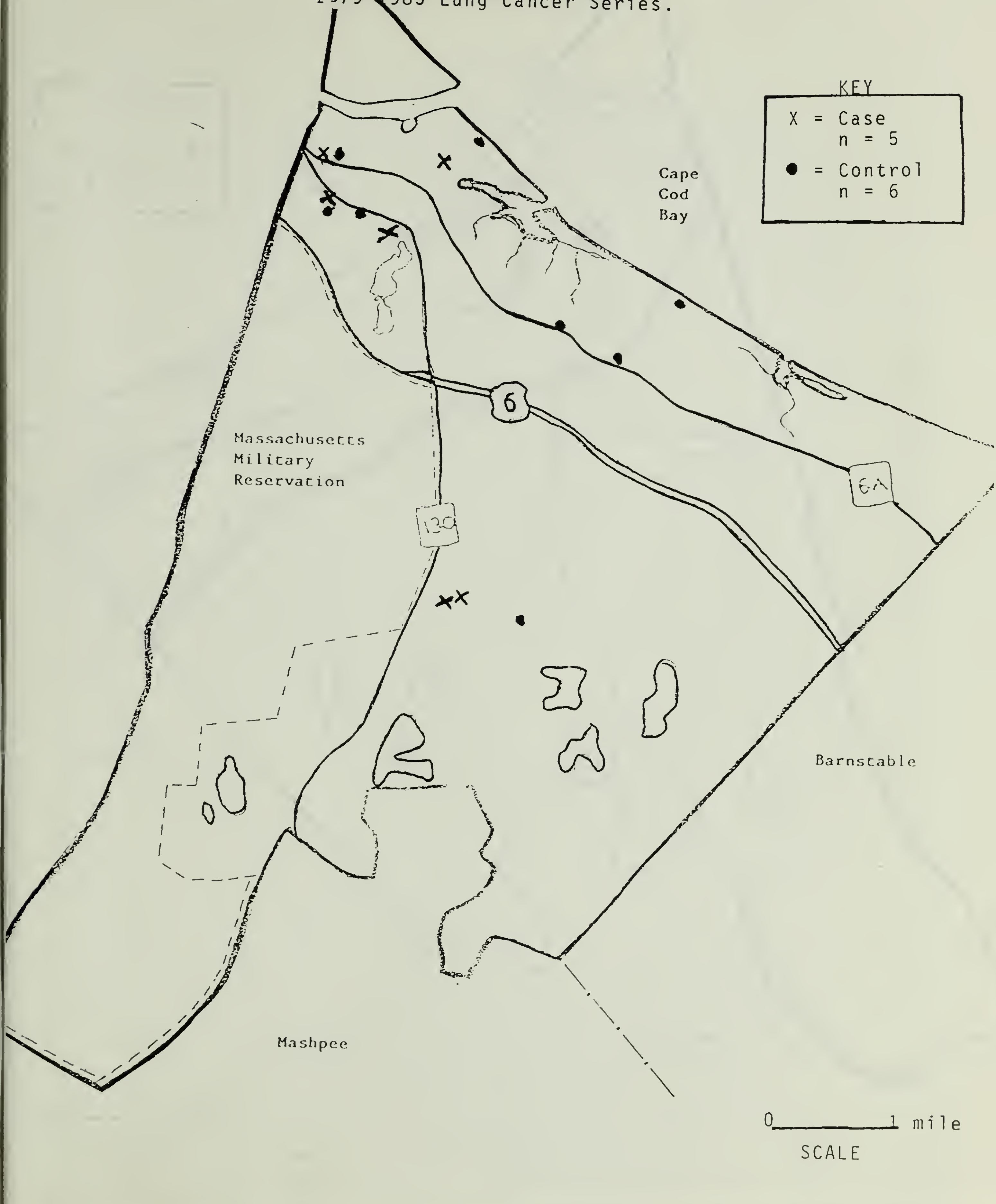


*Two cases had occupied two residences.

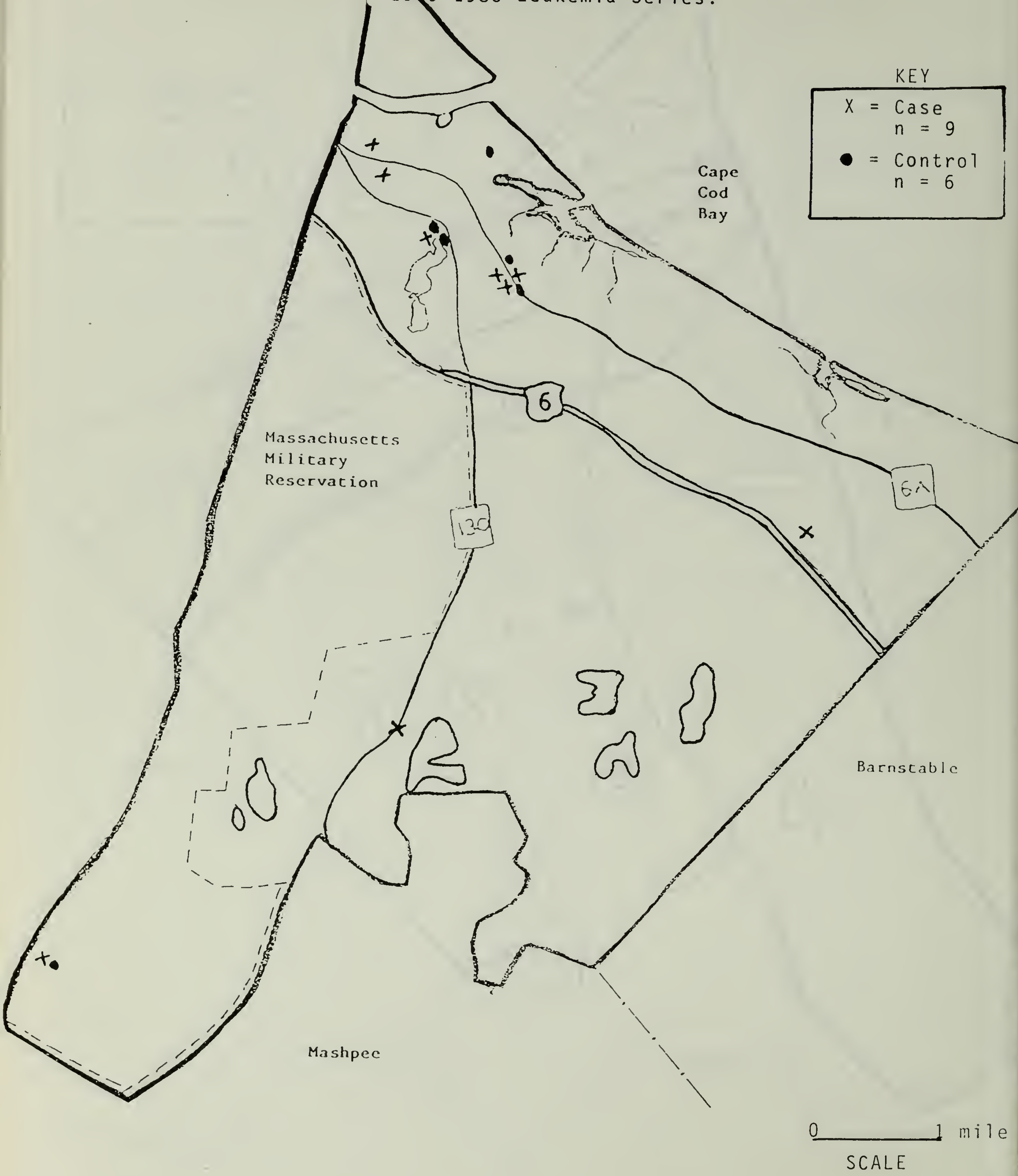
Map 13. Locations in Sandwich of Residences Occupied by Cases and Controls who Met the "10+ Years" Residence Requirement-- 1969-1978 Lung Cancer Series.



Map 14. Locations in Sandwich of Residences Occupied by Cases and Controls who Met the "10+ Years" Residence Requirement-- 1979-1985 Lung Cancer Series.



Map 15. Locations in Sandwich of Residences Occupied by Cases and Controls who Met the "5+ Years" Residence Requirement-- 1969-1985 Leukemia Series.



APPENDIX IV

ABBREVIATIONS

DEQE	Massachusetts Department of Environmental Quality Engineering
EPA	Environmental Protection Agency
IARC	International Agency for Research on Cancer
IRP	Installation Restoration Program
MDPH	Massachusetts Department of Public Health
MMR	Massachusetts Military Reservation
NS	Not Statistically Significant
PAVE PAWS	Precision Acquisition Vehicle Entry Phased Array Warning System
RFR	Radio Frequency Radiation
SD	Standard Deviation
SES	Socioeconomic Status
SMR	Standardized Mortality Ratio
TCE	Trichloroethylene
TCEA	1,1,1-Trichloroethane
USGS	United States Geological Survey
VOC	Volatile Organic Compound